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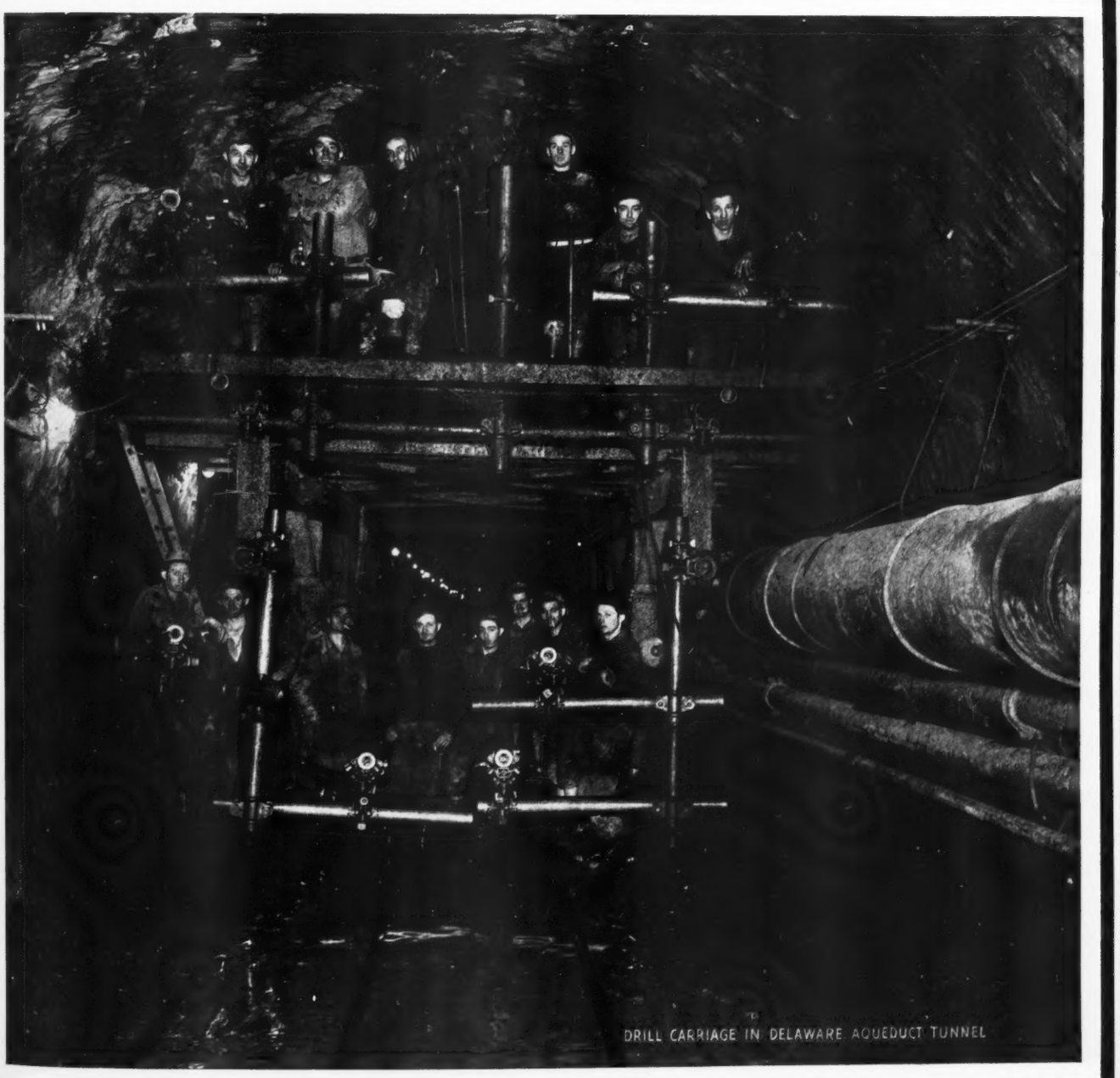

DRILL CARRIAGE IN DELAWARE AQUEDUCT TUNNEL

The D-100 POWERPLUS Grinder for 6" wheels weighs only 9 3/4 lbs!

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ROTOR TOOL COMPANY

CLEVELAND, OHIO

ON THE COVER

OUR cover picture shows the drill-carriage end of a jumbo being used by the Walsh Construction Company in the Delaware Aqueduct that will augment New York City's water supply. The jumbo, a structural-steel assembly that travels on tracks of 9-foot gauge, serves the dual purpose of a platform for seven Ingersoll-Rand S-70 power-feed drifter drills and of a "cherry picker" that facilitates shifting muck cars to and from a heading during loading operations. Details of the procedure are given in the leading article.

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IN THIS ISSUE

IN THE old-time hand-drilling contests that formerly were popular in the West, no mark was recognized as official unless it was made in granite that had been quarried near Gunnison, Colo. Similarly, the time was set at fifteen minutes, and everything was done to make all other conditions among the competitors equal. Strict regulation of these matters was necessary because it was early recognized that many variables affect the speed of drilling rock. As conditions under which tunnels are driven cannot possibly be made to correspond, it is difficult to determine what constitutes a record in that line of endeavor. There probably never were two jobs of this kind in which the size of the bores and the drilling characteristics of the rock were identical. Accordingly, the most we can truthfully say of any tunnel-driving performance is that it is outstanding. Such an appraisal must be made of the progress that has been registered by the Walsh Construction Company on Contract 316 on the Delaware Aqueduct. The driving of 3,100 feet of 17½-foot bore from two headings in 31 working days certainly ranks among the best marks ever recorded, and merits high praise for all concerned. Our leading article describes how the work is being done.

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THE article on modern submarines, beginning on page 6123, sheds much light on the progress that has been made in improving underwater craft, which play an important part in naval warfare. It bears the approval of the U.S. Navy Department. In a later issue we expect to publish an article on the modern torpedo by the same author, Robert G. Skerrett.

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IN The second article by A. D. Karr, he continues his enlightening discussion of the fundamentals of condenser design.

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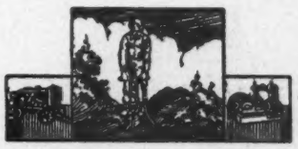

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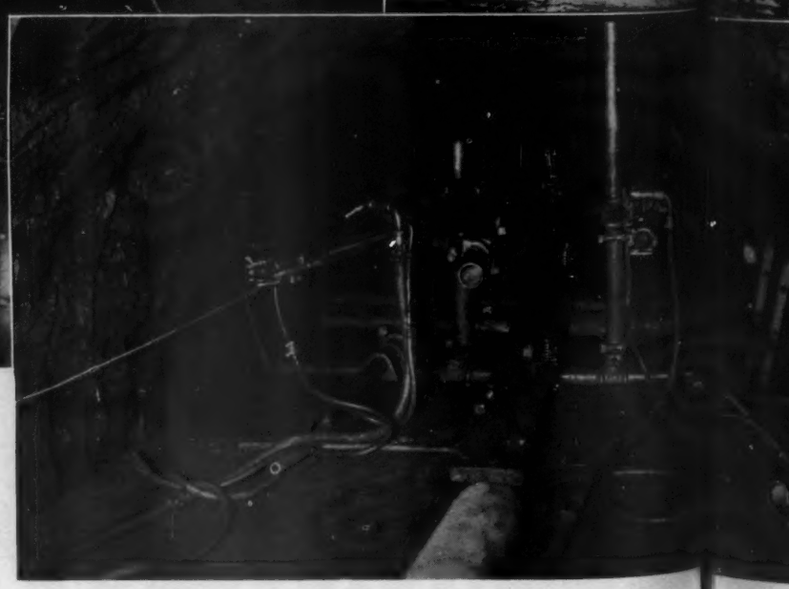
Making Every Minute Count in Tunnel Drivin

Richard S. Byers

General Superintendent, Contract 316, Delaware Aqueduct



FINISHED TUNNEL AND DRILLS

Above is a view toward the south heading being driven from Shaft 4. Notice the evenness with which the rock has been broken and the straightness and good appearance of the tracks. At the left are the large vent pipe and the compressed-air and water lines extending up to the heading. The picture at the right was taken from the top of a jumbo and shows three of the seven drifter drills mounted on one end of it.

THE driving of 3,100 feet of tunnel, about 17½ feet in diameter, with two headings from a single shaft in the short span of 31 working days is the record that was recently made by the Walsh Construction Company on the Delaware Aqueduct under Contract 316. That exceptional performance shows what can be done by wide-awake men, with up-to-date equipment, when on their toes and bent upon making every minute of their working time count in breaking through the rock.

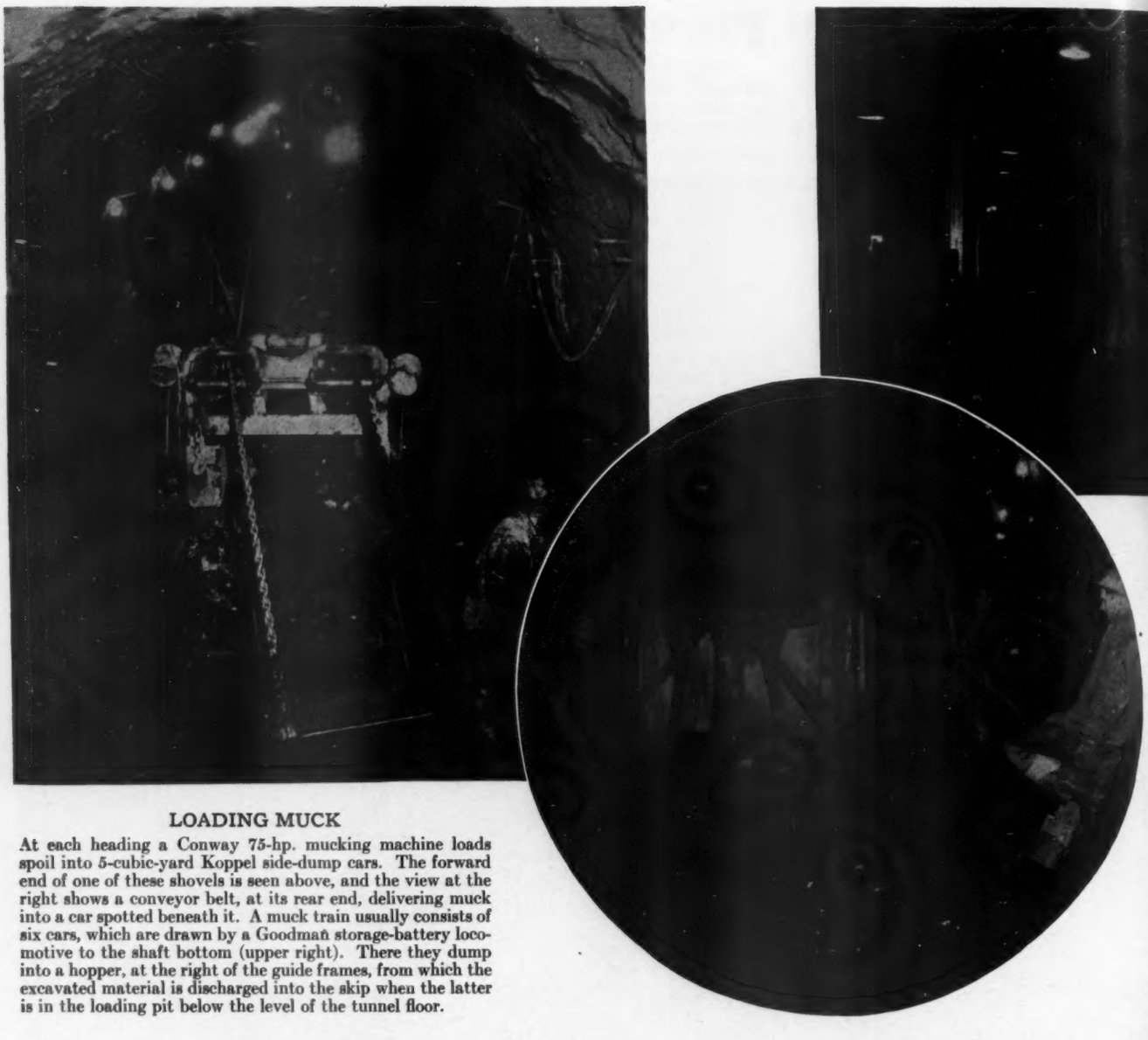
Speed in building the Delaware Aqueduct is not just living up to an engineering schedule on another big job. In this case it will mean giving to New York, a city of more than 7,500,000 people, a much-needed, increased supply of water that will not fail in time of drought and that will help to take care of its steadily growing population. The men on Contract 316, which covers a little more than 9 miles of tunnel, are aware of the situation; and the record recently made by them is proof of their desire to hasten relief.

Contract 316 is a part of the Rondout-West Branch Tunnel, one of three main pressure tunnels now under construction that are to link the Rondout Reservoir in the Catskills with the Hill View Reservoir, 85 miles distant, located just outside the northern boundary of New York City. The Rondout-West Branch Tunnel, about 45 miles long, will carry the impounded water from the Neversink River and Rondout Creek to the West Branch Reservoir that lies east of the Hudson River in a high section of the Croton watershed, and from the West Branch Reservoir the water from the Catskill Mountains and the Croton watershed will flow 40 miles southward through two pressure tunnels to the Hill View Reservoir.

In its finished form, the Rondout-West Branch Tunnel is to have, after its concrete lining is in place, a diameter of 13½ feet. In the first stage of the development, the tunnel will convey 170,000,000 gallons of water daily to the city; but its capacity will enable it to transmit 700,000,000 gallons every 24 hours when the second and third stages of the Delaware Project have been completed. The second stage will include a dam and a reservoir on the East Branch of the Delaware and the driving of a tunnel 26½ miles long that will discharge daily into the Rondout Reservoir 370,000,000 gallons of mountain water. The third stage will require reservoirs on the Little Delaware River, the Beaver Kill, and the Willowemoc

SHAFT HEADFRAME

This structural-steel tower (upper left) rises 125 feet above Shaft 4, which extends to a depth of 880 feet and is similar to the headframe at Shaft 5. It is equipped with an automatic tipple that dumps a 12-cubic-yard skip into an elevated hopper. From the hopper the muck is loaded into 4-cubic-yard trucks through a chute that is provided with an air-operated gate (directly above). Only a few trucks are required, as spoil is disposed of close by.



LOADING MUCK

At each heading a Conway 75-hp. mucking machine loads spoil into 5-cubic-yard Koppel side-dump cars. The forward end of one of these shovels is seen above, and the view at the right shows a conveyor belt, at its rear end, delivering muck into a car spotted beneath it. A muck train usually consists of six cars, which are drawn by a Goodman storage-battery locomotive to the shaft bottom (upper right). There they dump into a hopper, at the right of the guide frames, from which the excavated material is discharged into the skip when the latter is in the loading pit below the level of the tunnel floor.

Creek, together with the necessary connecting tunnels, which will make available a further supply from the slopes of the Catskills of 160,000,000 gallons of water daily. This water also will be diverted into the Rondout Reservoir. The work now in hand, which involves the Merriman Dam on Rondout Creek, a dam on the Neversink River, an interconnecting tunnel about 5 miles long, and the 85 miles of tunneling and other features between the Rondout and the Hill View reservoirs, will cost, according to the estimates, $210,174,000.

The line traced by the Rondout-West Branch Tunnel runs from northwest to southeast, and the 9-mile stretch being driven by the Walsh Construction Company underlies the hilly country of Ulster County, New York, westward of the Hudson River, and passes beneath the towns of Gardiner, Plattekill, and Marlboro. The work would probably be unnoticed from any of the neighboring highways but for the two red-painted, tall skeleton towers of steel which might easily be mistaken for aviation beacons. The towers are the headframes at Shaft 4 and Shaft 5, respectively. Each is 125 feet high between the ground and the bull wheels and is directly over its shaft which extends down to the projected tunnel line. Shaft 4 was sunk to a depth of 880 feet, and Shaft 5 to a depth of 1,010 feet—the two being 23,649 feet apart, or about 4½ miles. They are circular in cross section and each has a diameter of 14 feet within its concrete lining.

Shaft-sinking also included the turning of the tunnel headings at the bottom and the excavating of approximately 200 feet of tunnel north and south of each shaft. It was done by another contractor in 1937-1938. The short tunnel stubs were advanced to disclose the nature and the condition of the rock to be penetrated in excavating the tunnel sections and to enable the successful bidder to install his permanent tunnel-driving plants immediately following the award of his contract so as to save time in getting started. For the protection of the shafts during the interval between their completion and the beginning of the main tunneling operations their openings were sealed at the top by tight timber covers. Such was the state of the work when Contract 316 was given the Walsh Construction Company by the Board of Water Supply of the City of New York on March 30, 1939—the estimated price being $11,111,111.11.

On April 5 of last year—six days after the award—the Walsh Construction Company was served notice to begin operations. Under the contract it was allowed five months from that date in which to install the plants at Shafts 4 and 5 and be ready to start driving north and south from each shaft along the tunnel line. Further, the company was given six months from the date of the order to start in which to drive a total of 1,600 feet, or 400 feet of tunnel at each heading. But the situation was not as favorable as it might appear.

The period between the sinking of the two shafts and the award of the contract was long enough for them to become flood-

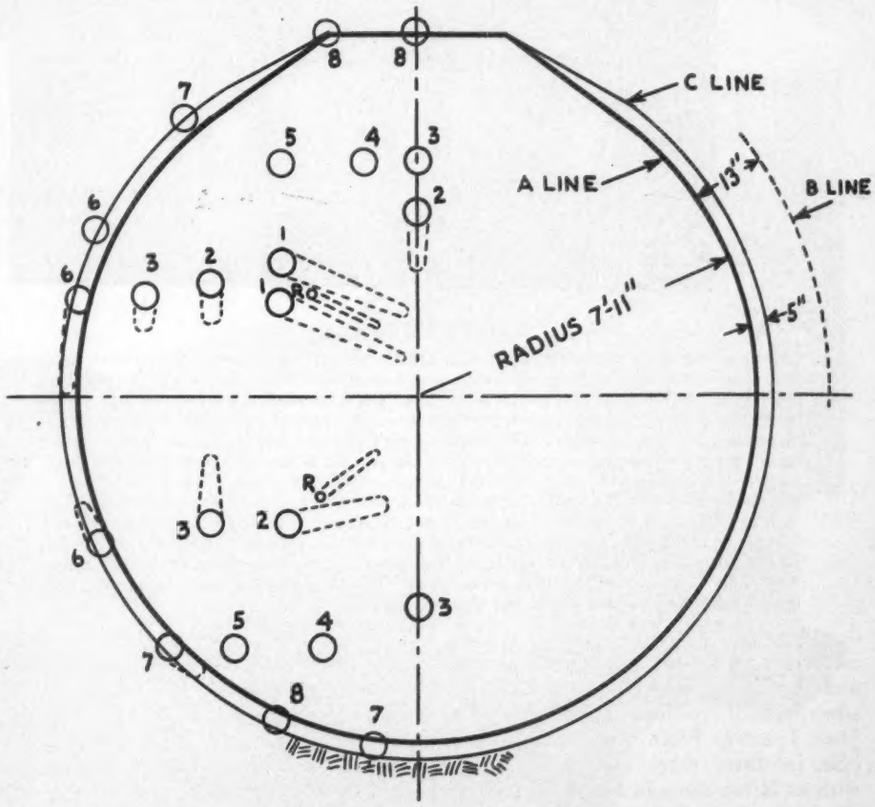
ed; and the shafts and the stub tunnels had to be unwatered before the Walsh Construction Company could get down to the tunnel level and make ready for the driving operations. The unwatering was done with two electrically driven Ingersoll-Rand Class CMRV pumps carried on a raft in each shaft. One unit did all the work down to half the depth, and then the two pumps, operating in tandem, completed the job to the bottom. As soon as both were drained, the contractor made the necessary enlargements at the bottom of each shaft for a skip pit, sump, pump chamber, etc., all of which was part of the preparatory work that was started at Shaft 5 on April 17 and at Shaft 4 nine days later. During that stage of the activities, a timber headframe and an electric hoist were placed at the top of each shaft and were of aid during the unwatering operations in placing steel guides in the shaft and in performing other services. The temporary timber headframes were later supplanted by the tall steel headframes previously mentioned.

The headframes are constructed of fabricated structural-steel members bolted together so as to facilitate dismantling. Each cast-steel sheave or bull ring at the top of a frame is 12 feet in diameter. The steel hoist cables are 2⅛ inches in diameter, and each is 1,500 feet long and has a breaking strength of 490,000 pounds. Each headframe is served by a Lidgerwood hoist, that has an 8-foot-diameter drum and is driven by a 600-hp. motor, and also by a man-and-material cage 12½ feet long. Directly beneath the cage and connected with it is a skip having a capacity of 12 cubic yards (water measurement). This is of the tipple type, and automatically tilts and discharges when reaching the level of a chute that carries the muck into a hopper placed high enough above ground to load a motor truck spotted beneath it. The hopper gate is opened and closed pneumatically. The cage and skip, with the latter loaded, weigh 28 tons; and there is a 22-ton counterweight that travels in guides extending down the shaft. The cage runs at a speed of 750 feet a minute; and at Shaft 4 the loaded skip can be hoisted, emptied, and returned to the loading position underground in three minutes. At one side of the skip pit, which is below the tunnel level, there is a hopper into which the muck cars dump directly and which is large enough to hold the full contents of two cars. The bottom gate of the hopper chute is lifted and lowered by three pneumatic-piston hoists and discharges the excavated material into the waiting skip.

Although there was a delay of some days in the delivery of the cages and skips, still tunneling was started at Shaft 5 on August 5 and at Shaft 4 on August 15 of the year gone. Work at Shaft 4 was undertaken just four months and ten days after the contractor was served notice to begin—the better part of a month short of the time limit set by the contract. Further, instead of the specified 1,600 feet of tunneling at the four headings at the end of the first six months of operation, the Walsh Construction Company exceeded requirements and had 5,846 linear feet to its credit—4,246 feet better than the schedule. That performance was due both to the mechanical facilities provided for the job and the spirit shown by the men in pushing forward.

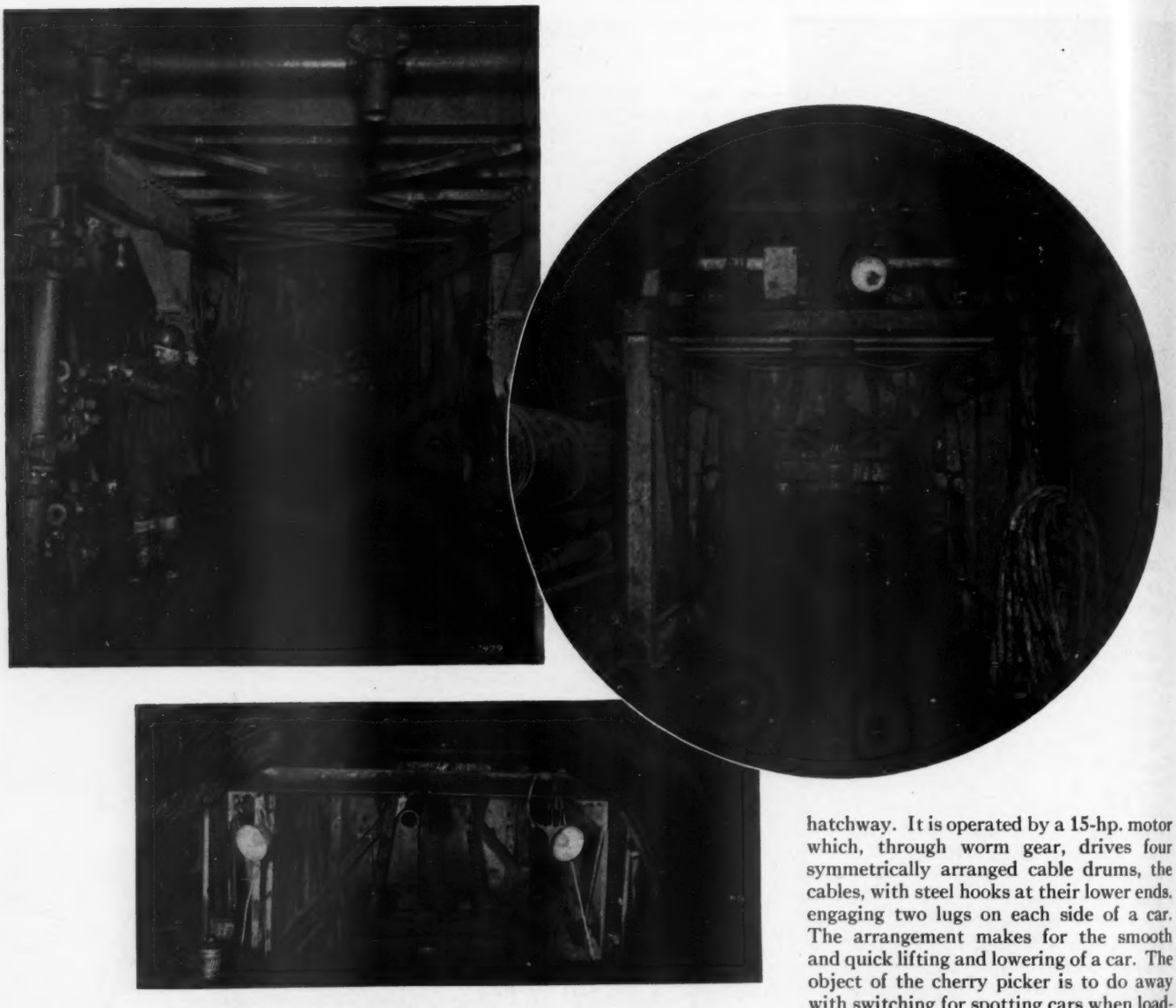
In the interval since that advance was made, the men have got into full swing and have gradually bettered their records. How much they have improved is indicated by what was done at Shaft 4 during the 31 working days of the current year starting January 11. Tunneling is carried on six days a week with three 8-hour shifts each 24 hours. Within that period the north heading was driven 1,481 linear feet and the south heading 1,619 feet—a combined advance of 3100 feet. This progress was made in a formation known as Hudson River shale, a good-drilling and comparatively soft rock.

To understand how we have been able to forge ahead so fast, let me describe the equipment above and below ground at each shaft. Above ground there is a high-pressure compressor plant of two machines, each with a capacity of 3,000 cfm. and driven by a 600-hp. motor. In addition there is a blower plant also consisting of two units each driven by a 150-hp. motor and having a rated capacity of 10,000 cfm. Three-phase, 60-cycle current at 2,300 volts is used to operate the compressors and the blowers. Among the buildings at each shaft are a dryhouse, a battery-charging station, a storehouse, and a blacksmith shop which contains the following I-R equipment: two



TYPICAL DRILL ROUND

The location of the drill holes is shown in half the area and is the same for the other half. The *R* holes are cut holes, and are fired instantaneously. The other holes are fired with delays, in the order designated. The *A* line is the theoretical boundary of the excavated tunnel. The *B* line marks the limit beyond which any rock broken out must be paid for by the contractor, the reason being that the voids must be filled with concrete. The *C* line is the assumed average outward limit of the concrete lining that is to be placed later, and is therefore the line to which the contractor endeavors to excavate.



"CHERRY PICKER"

Cherry picker is the name applied to any apparatus that is designed to eliminate car switching in transferring a loaded carrier back from a tunnel face and moving an empty one to the head of the train at the muck pile. On Contract 316 this is accomplished by elevating an empty car taken from the rear of the train and running the remaining units back from the heading. The empty is then lowered and forms the head of the train. By repeating this procedure, each of the six cars of the train can be shifted, in turn, to the loading position. The cherry picker, one end of which is the drill carriage, has an opening near the middle through which each car is lifted. This is done by attaching to a car four cables which are wound upon four drums driven in unison by a 15-hp. electric motor. At the upper right are seen two such drums at one end of a jumbo, as well as a car being lifted. At the upper left is a view through the passageway of the jumbo from the drill-carriage end. The third picture was taken from the top of the jumbo with a car in the elevated position.

oil furnaces, a sharpener, a cut-off machine, and a pedestal grinder for conditioning drill steels, etc. There is a first-aid station at Shaft 4; but at Shaft 5, where the general office is located, there is a first-aid hospital with an X-ray room in charge of a physician and a male nurse.

The underground equipment for each heading includes a jumbo that travels on a track of 9-foot gauge and that does double duty as a drill carriage and an up-to-date form of "cherry picker." It is strongly built of structural-steel members, and in cross section is like an inverted rectangular "U" mounted on wheels. It straddles the track so as to leave a free passageway for muck trains moving to and from the heading. At the forward end and at the sides and top, the jumbo carries columns and bars for the mounting of seven Ingersoll-Rand Type S-70 power-feed wet drifters. At the top of the structure, near midlength, there is a hatchway large enough to lift through it the body of a muck car so that it can be suspended clear of the muck train moving beneath it on the central track of 3-foot gauge. For this purpose there is an electric hoist on top of the jumbo at the hatchway. It is operated by a 15-hp. motor which, through worm gear, drives four symmetrically arranged cable drums, the cables, with steel hooks at their lower ends, engaging two lugs on each side of a car. The arrangement makes for the smooth and quick lifting and lowering of a car. The object of the cherry picker is to do away with switching for spotting cars when loading them, one after the other, at the end of the mucking machine, which is an electrically driven 75-hp. Conway unit. The shovel dumps on to a broad rubber belt conveyor that carries the spoil rearward and drops it into the waiting car.

The muck cars are of the Koppel side-dump type and each has a capacity of 5 cubic yards. A loaded car can be easily dumped by one man. A train is usually made up of six cars hauled by a Goodman storage-battery locomotive—the storage battery being changed every eight hours. When a train of empties moves up to the mucking machine, one of the cars is at the head with the locomotive next and four cars trailing behind. The sixth one is held suspended by the cherry picker. When the front car is loaded, the train is backed far enough into the jumbo for the sixth empty to be lowered to head the train, which then goes forward so that the cherry picker can pick up another of the trailing empties. The train is next pushed up to the mucking machine, the head car is loaded, and the routine just described is repeated. This continues until all the cars are loaded, and

by that time the locomotive is at the outer end of the train ready to run to the loading hopper at the bottom of the shaft.

During the mucking period, the jumbo is stationed about 200 feet back from the heading. It takes from a half to two minutes to load a car and from one-half to a full minute to shift a car. Mucking usually requires from one and a half to two hours after each shot, and in that time the cherry picker will lift and lower from 38 to 40 cars. The muck trains run on 60-pound rails, while the track from the jumbo to the heading is laid in unit sections, 7½ feet long, assembled with bolted metal crossties. Each section has projecting lugs that overlap the adjoining sections, and a single bolt serves to make a connection. The work of shifting and placing them by hand can therefore be done quickly. Four of these assembled units occupy the space of a regular 30-foot section; and the track is laid on timber crossties as the jumbo is moved ahead.

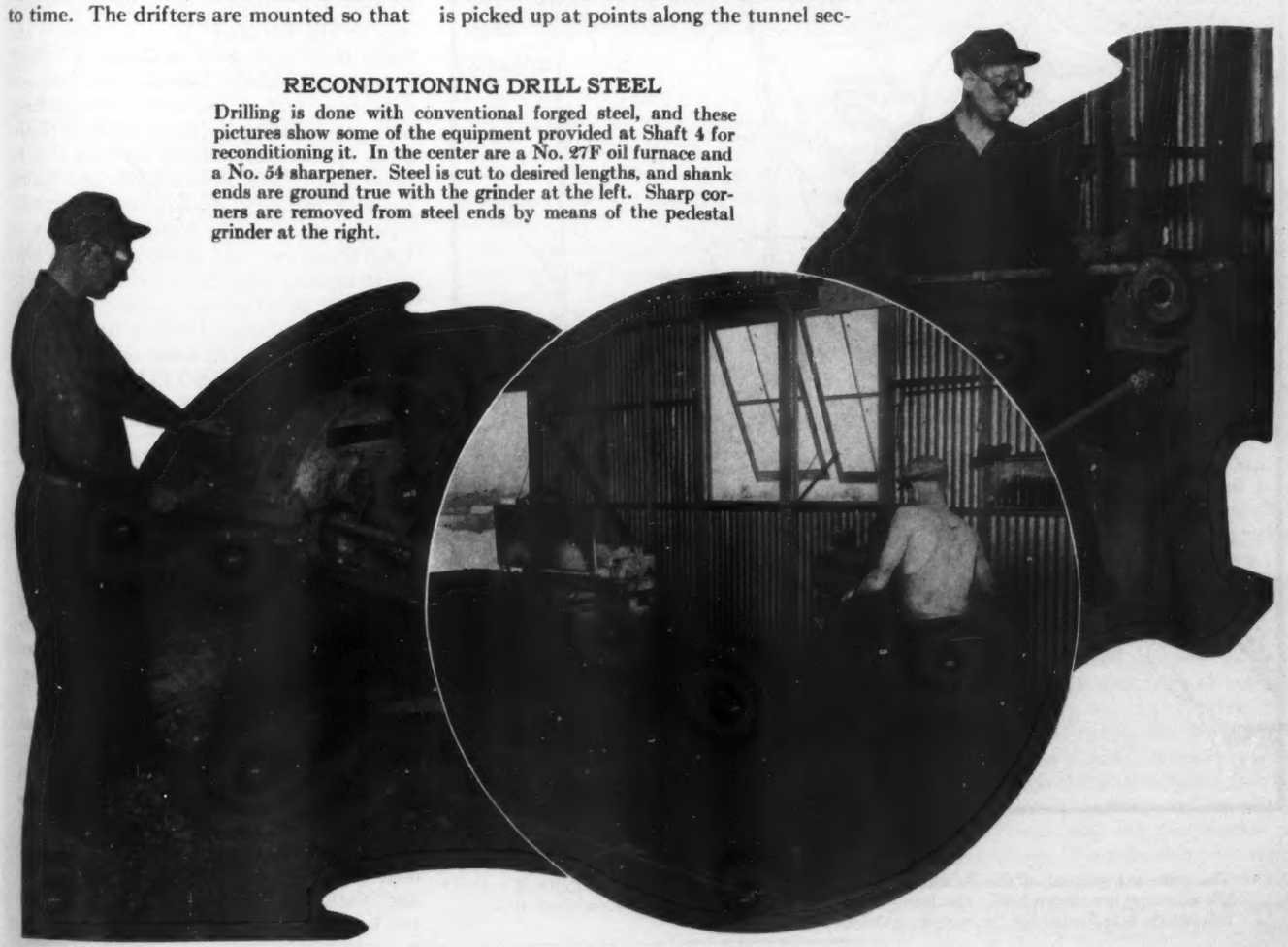
When mucking is finished, the drill carriage is pushed up to the cleared heading by the locomotive, a wire cable, stretched between opposite columns of the jumbo, serving as a temporary bridle for the locomotive. When the jumbo is blocked in place, and the air and water connections are made for the drills, then the latter can start their work on a round of from 40 to 55 holes—the number depending upon the hardness of the rock, which varies from time to time. The drifters are mounted so that they can be swung to drive any of the required holes. Generally, the cut holes are 12 feet deep, while the relievers and the trim holes are 11 feet deep. At each round, the pull approximates 10 feet. A typical round is shown in an accompanying sketch. From 7 to 8 pounds of dynamite is loaded in each hole, with about 400 pounds for a round. In firing a round, we use direct shots for the cut holes with from first to eighth delays for the remaining holes. The firing station in each case is 1,500 to 2,000 feet back from the heading, and direct current of 220 volts is employed.

Drilling is done with 1¼-inch hollow steel and with 30-inch changes. The steels are made up in 3-, 6-, 9-, and 12-foot lengths. The starting bits are 2¼ inches in diameter, with a ⅛-inch reduction at each change of steel and with bottom bits of 1⅝ inches. So far the rock has broken with marked evenness, as some of the photographs show; and advance has been slowed up only when we have run into streaks of abrasive sandstone. The character of the rock so far penetrated has been exceptionally firm; and in the tunnel sections driven from Shaft 4, for instance, only 36 feet of steel roof support has been needed because of weak or faulty rock. Some roof support was installed at the bottom of the shaft by the contractor who did that work.

During driving, we have had to deal with but little water. What water does come in is picked up at points along the tunnel sections with pneumatic pumps and is either delivered to or allowed to drain in to the sump at the bottom of each shaft. When the quantity justifies it, it is lifted to the ground surface by a 350-gpm. electric pump or by any or all of three Type MRV, 30-hp. Motorpumps, which do the work ordinarily and do it economically.

When a shot is fired, the ventilating unit is used for about fifteen minutes to suck the gases away from the heading. During that time, a combination air-and-water spray curtain is in operation at a point about 100 feet back from the working face and fans out in the direction of the face. This curtain has been found effective in preventing the gases from billowing back into the tunnel generally. In other words, "gassing out" has actually been reduced to evacuating a given area, which in this case is approximately 17½ feet in diameter and 100 feet in length. After fifteen minutes, the ventilating flow is reversed and fresh air, at the rate of 10,000 cfm., is blown toward the heading preparatory to starting mucking and other operations such as scaling the roof and the side walls, and then painting the tunnel section in white on the face of the newly exposed rock to guide the drill runners for the next round.

The ventilating pipe is 26 inches in diameter, is formed of ⅛-inch sheet steel, and is coated inside and out. Each section



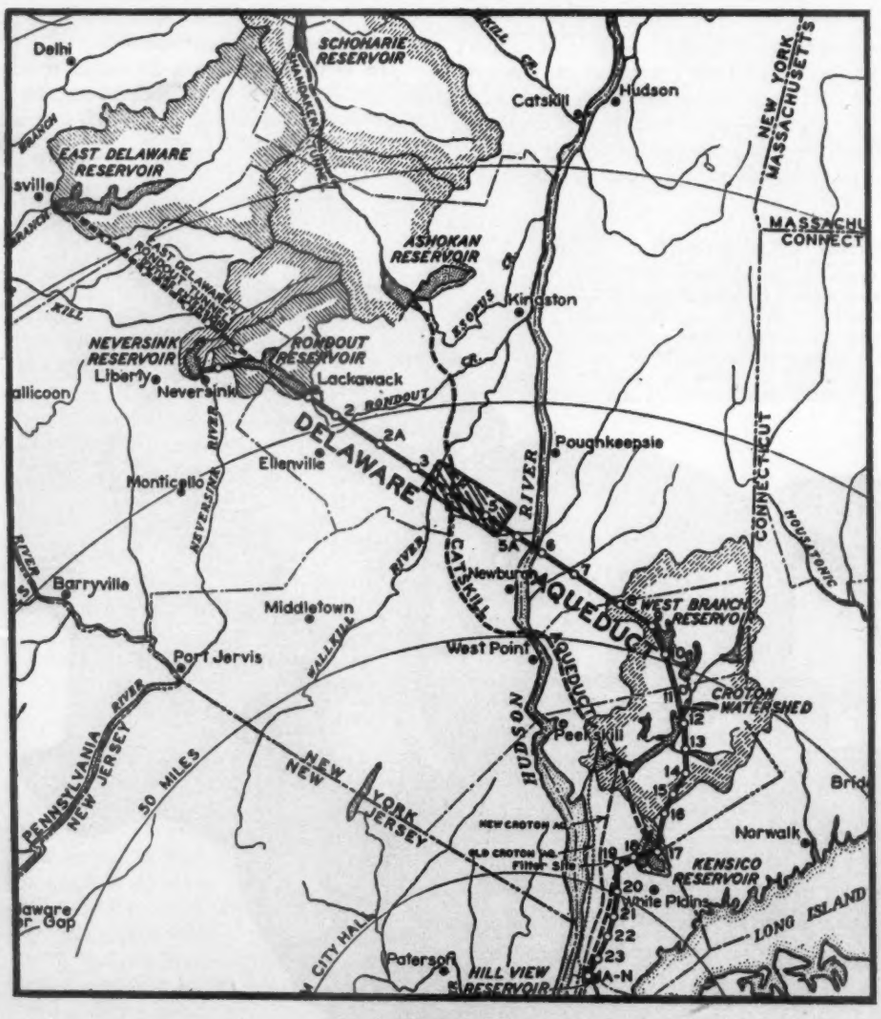
RECONDITIONING DRILL STEEL

Drilling is done with conventional forged steel, and these pictures show some of the equipment provided at Shaft 4 for reconditioning it. In the center are a No. 27F oil furnace and a No. 54 sharpener. Steel is cut to desired lengths, and shank ends are ground true with the grinder at the left. Sharp corners are removed from steel ends by means of the pedestal grinder at the right.

has an average length of 24 feet and is finished with a bell at one end and a spigot at the other. Adjoining units are pulled together against a round, rubber gasket which is held in a recess and are drawn tight by means of screw bolts passing through opposing lugs on the sections. Compressed air is carried to the heading by a 6-inch main; and another 6-inch line withdraws water from it and from other points in the working area. A 2½-inch main delivers water to the drills and for other purposes at or near the face. Electric energy for different uses on Contract 316 is transmitted to each shaft site at 13,200 volts and is stepped down to 2,300 volts before it is sent down into the tunnel. There it is further stepped down to 440 volts for operating machinery and to 220 volts for lighting and for shooting. The current is supplied by the Central Hudson Gas & Electric Corporation.

The 48,145 feet of tunnel within the limits of the contract extends northward from Shaft 4 for 2.45 miles and southward from Shaft 5 for 2.19 miles; and with the 4.48 miles between the two shafts, the entire job will have a span of 9.12 miles. There are no living quarters for the force at either shaft; but the men are housed in the nearby towns of Newburgh, Gardiner, Plattekill, and Marlboro, or come from outlying districts up to 10 or 15 miles away.

The Rondout-West Branch Tunnel at Shaft 4, which is in the Valley of the Wallkill River, underruns the existing Catskill Aqueduct which was driven across and beneath the same valley about 25 years ago. A blow-off shaft rises from the Catskill Aqueduct only a few hundred feet from Shaft 4, and this has enabled the Walsh Construction Company to obtain at all times an ample supply of water for its operations at that shaft. The writer of this article worked on the Catskill Aqueduct, and was actually engaged in driving the tunnel under the Wallkill and thus acquired his knowledge of the rock that has to be penetrated in putting through the present undertaking. His interest now is all the keener because the job in hand is being pushed with mechanical aids that did not exist when the Catskill Aqueduct was under construction. These facilities are making it possible to hang up records that could not have been made on the earlier project.



LOCATION MAP

The principal features of the Delaware River water-supply project and the route of the aqueduct are shown here. The location of the 9-mile tunnel contract described in this article is indicated by the cross-hatched area.

DIRECTING THE WORK

Left to right: Alexander Simpson, superintendent, Shaft 5; Richard S. Byers, general superintendent; and George Underwood, superintendent, Shaft 4.

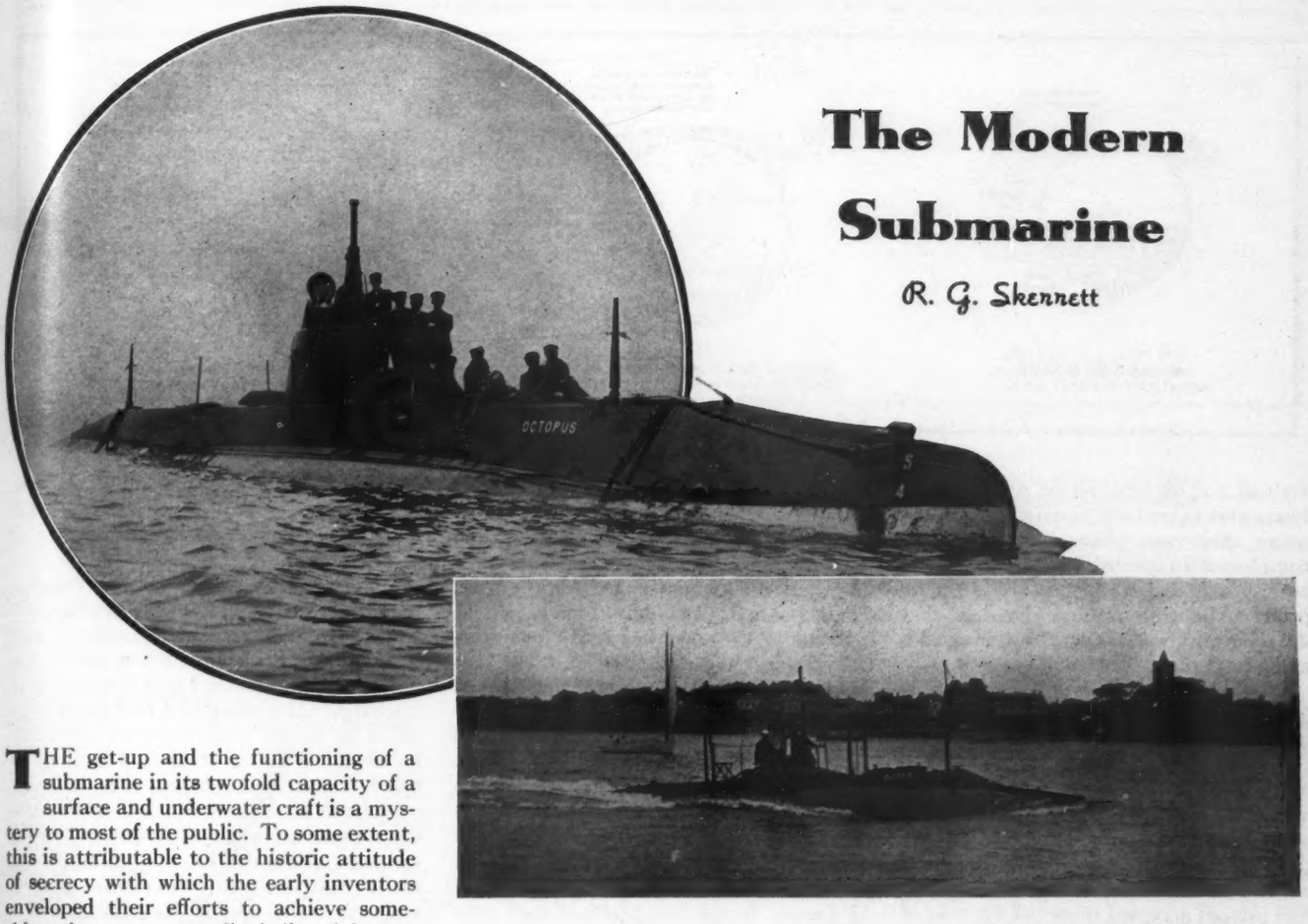
Unless unexpected conditions are encountered in the rock still ahead, there is good reason to believe that the two headings now approaching each other between Shaft 4 and Shaft 5 will hole through sometime in July of this year; and it is even likely, should the rock continue to be favorable, that the meeting may take place during the month of June. There is much friendly competition among all four headings on the job; and the performances already made may even be bettered before tunneling is ended. Indeed, since this account was drafted, the work accomplished at the two headings being driven from Shaft 5 is a further indication of the pace that is being maintained. Between February 1 and March 8, inclusive, the advance made in 31 working days at the north heading was 1,863 linear feet, and at the same time the south heading progressed 1,150 linear feet. The north heading was in shale, while the drillers in the south heading had to deal with sandstone. The total advance from Shaft 5 was, therefore, 3,013 linear feet.

The men in charge of the work for the contractor are William A. Durkin, job manager; the writer, who is general superintendent; George Underwood, shaft superintendent at Shaft 4; and Alexander Simpson, shaft superintendent at Shaft 5. The officers of the Walsh Construction Company are: Thomas J. Walsh, president; David Small, vice-president; J. Henry Gill, vice-president; William A. Durkin, vice-president and job manager; Edward P. Walsh, treasurer; and John S. Macdonald, chief engineer.

The entire Delaware Project was conceived and is being carried forward under the Board of Water Supply of the City of New York, and the great task is under the general direction of Walter E. Spear, chief engineer. Neil C. Holdredge is department engineer, D. W. Howes is division engineer, and Nathan Trace is resident engineer for the board.

The Modern Submarine

R. G. Skennett



EARLY SUBMARINES

The lower picture shows the U.S. Submarine "Adder," one of a group of six boats ordered by the Navy Department in 1900. Each craft was 63¼ feet long and displaced 103 tons at the surface and 122 tons submerged. It had a single torpedo tube and a personnel of seven. The "Octopus," built in 1906 and having a displacement of 255 tons when submerged, is shown at the top. She had a nonwatertight superstructure of increased size that served to improve her sea-going qualities.

THE submarine added to the U. S. Navy in 1900 displaced 75 tons submerged and made a maximum speed of 6 knots at the surface in smooth water. Today, the largest of our underwater boats displaces 4,080 tons submerged, and the latest of the sea-going type are credited with a surface speed of 20 knots. Forty years ago our submarines had pressure hulls designed to withstand a submergence of 150 feet: our new boats are tested at a submergence of 300 feet and their hulls are said to be strong enough to withstand the pressure of the sea at a depth of 450 feet.

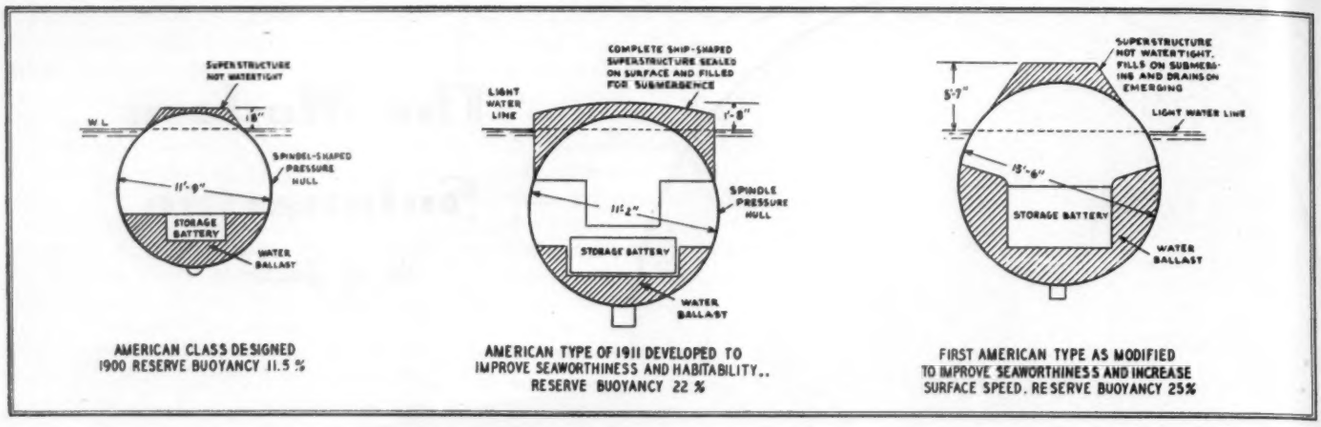
The submarine is no longer an experimental craft, as it was four decades back. It is recognized today as a type of vessel that can actively co-operate with the sea-going battle fleet and remain self-sufficient in the open ocean and far from any base of supply for two or more months running. Much of the effectiveness of the present-day submarine is directly due to the varied and skillful application of compressed air in its operation.

THE get-up and the functioning of a submarine in its twofold capacity of a surface and underwater craft is a mystery to most of the public. To some extent, this is attributable to the historic attitude of secrecy with which the early inventors enveloped their efforts to achieve something that was generally believed impossible of accomplishment. In turn, governments adopted the same course even though that stand has seldom kept any nation from learning what other countries were doing in building submarine torpedo boats.

Americans should have a fuller understanding about our underwater craft and take pride in them because native genius blazed the way for the modern flotillas of that type. Furthermore, for something like four decades, our naval architects, marine engineers, other technicists, and artisans in many departments of our industrial life have given of their best to make our submarines capable of meeting successfully the conditions imposed by our very extensive seaboards and the nature of their approaches.

The numerous underwater boats of different sizes and varied characteristics that we have built since 1900 have all been experimental in a quest for the best; and in this respect they have not differed from the other types of battle ships evolved in the same period. As engineering advances, so changes take place in any navy; and what our submarines shall be in the years to come will depend upon what happens in other fighting fleets and how we shall have to measure forces when the day of contest arrives. Each sure step in this progress is determined by cumulative experience.

The World War was a revelation of what the submarine could do both when legitimately and otherwise employed; and those years of struggle showed the great value of that type of craft in a number of new directions in military service. During that period the British submarine flotillas devised an extremely effective technique of handling the vessels for offense and defense both in combating U-boats and in aiding the battle fleets and the movements of merchant vessels. For something like eight months in 1918 divisions of our submarines collaborated with the British in European waters—one being based on Bantry Bay,


SUPERSTRUCTURE NOT WATERTIGHT
W L
18"
SPINDEL-SHAPED PRESSURE HULL
11'-9"
STORAGE BATTERY
WATER BALLAST
AMERICAN CLASS DESIGNED 1900 RESERVE BUOYANCY 11.5 %
COMPLETE SHIP-SHAPED SUPERSTRUCTURE SEALED ON SURFACE AND FILLED FOR SUBMERGENCE
LIGHT WATER LINE
1'-8"
SPINDLE PRESSURE HULL
11'-2"
STORAGE BATTERY
WATER BALLAST
AMERICAN TYPE OF 1911 DEVELOPED TO IMPROVE SEAWORTHINESS AND HABITABILITY.. RESERVE BUOYANCY 22 %
SUPERSTRUCTURE NOT WATERTIGHT. FILLS ON SUBMERGING AND DRAINS ON EMERGING
5'-7"
LIGHT WATER LINE
13'-6"
STORAGE BATTERY
WATER BALLAST
FIRST AMERICAN TYPE AS MODIFIED TO IMPROVE SEAWORTHINESS AND INCREASE SURFACE SPEED. RESERVE BUOYANCY 25%

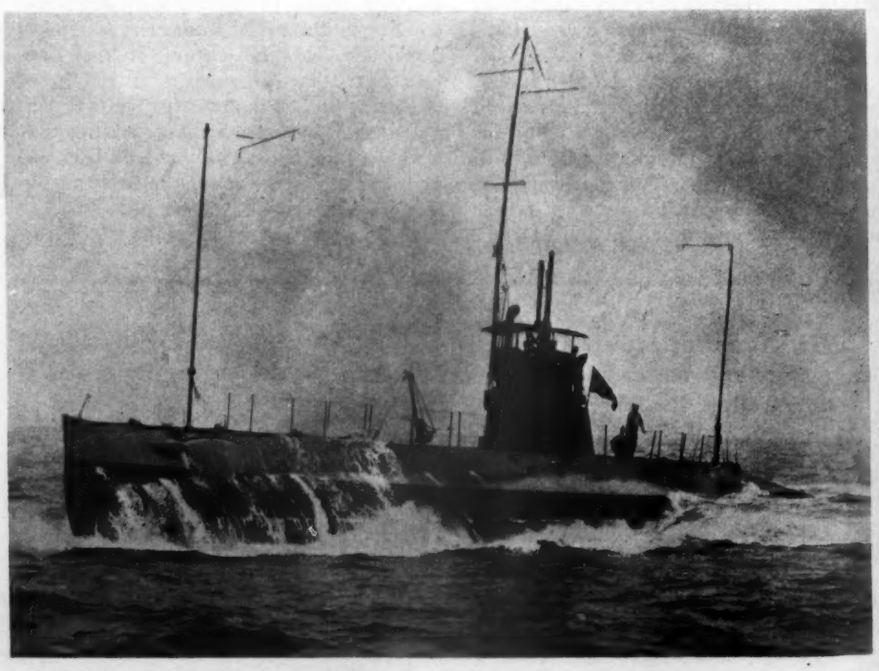
Ireland, and the other on the Azores. Those boats were never built to cross the Atlantic under their own power, nor were their complements expected to operate them in stormy seas and to live aboard them for protracted patrols offshore. Even so, they did their work well, despite staggering odds and a low order of habitability.

What the commanders of our submarines learned while in European waters and while patroling our Atlantic seaboard and the Caribbean approaches to the Panama Canal in 1917 and 1918, gave our naval experts a fund of data of inestimable value; and upon that information they have drawn since in designing and equipping the vessels we have in service and under construction. The present accepted theory of the field of usefulness of the submarine is radically unlike that generally held by the men of our navy up to the outbreak of the World War.

Originally, the submarine was reluctantly accepted as of possible use for harbor defense or for working a short distance offshore. The first of our boats, purchased in 1900, had a length of about 54 feet, a surface displacement of 67 tons, and took in but 8 tons of water ballast to put her in trim for a submerged run. That craft was driven on the surface by a 50-hp. gasoline engine, and under favorable conditions could make 6 knots. Underwater, her electric motor—drawing energy from a storage battery—could propel her at a maximum of 5.5 knots for one hour before overtaxing the batteries. The idea that the submarine was mainly for inshore operations was reflected in the vessels constructed by us and placed in commission up to 1915; and those that saw active service off the coast of Ireland and around the Azores were all of less than 550 tons submerged displacement and had surface speeds that were several knots less than the U-boats against which they were likely to be pitted.

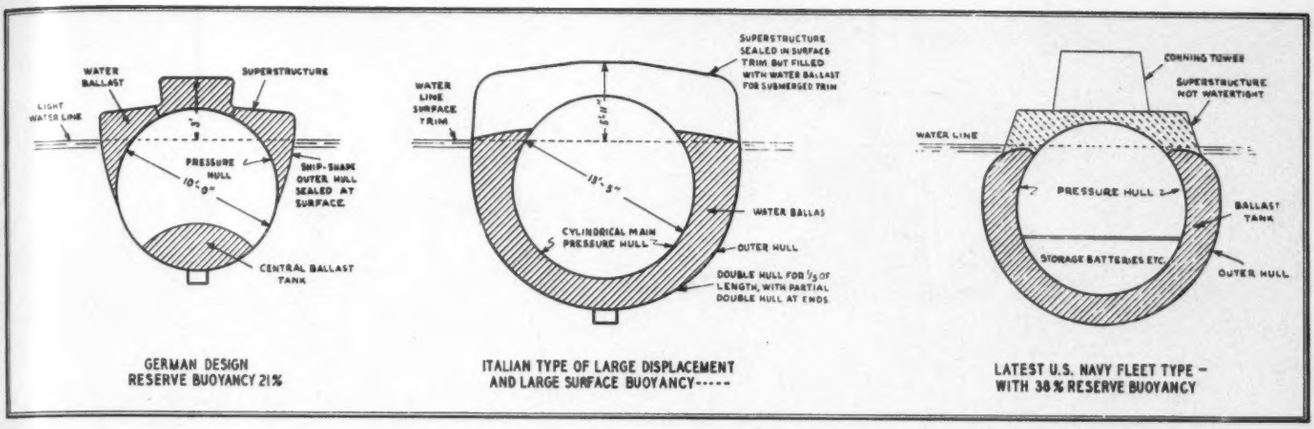
Today, our navy is building what are known as fleet submarines and cruiser submarines. The former are sea-going vessels of ample speed to accompany battle squadrons maneuvering far from our shores, while the latter also are seaworthy, of good speed, and capable of covering thousands of miles on a patrol detail before returning to a base to replenish their fuel and other necessary supplies. Two striking examples of our cruiser submarines are the *Narwhal* and *Nautilus*, completed ten years ago and now about to be reëngined so that they may be useful for another ten years or more. These boats displace 2,730 tons in surface trim and 3,960 tons when ready for underwater work, the difference of 1,230 tons being the volume of water ballast taken aboard to put them in readiness to dive. Each has an over-all length of 371 feet and an extreme beam of 33¼ feet, and will be driven by four 4-cycle Diesel engines arranged in tandem on two shafts. Each of these units has sixteen cylinders capable of developing 1,535 hp. At full speed the four engines will propel the craft at the rate of 18 knots. In the fuel tanks of each submarine can be stored enough oil for patroling cruises of from 4,000 to 5,000 miles at a speed ranging from 10 to 12 knots. In other words, on that service either one will have a self-contained sea endurance of about 90 days.

Submerged, the *Narwhal* or the *Nautilus*, drawing electric energy at the maximum 1-hour rate of discharge, will be able to cover substantially 8.5 knots; but normally the batteries would be used at a slower rate of discharge. At a speed of 4 to 5 knots they could be driven underwater continuously for about 24 hours. Contrary to popular belief, high speed submerged is not now considered of primary importance because the submarine, when underwater, plays a waiting game and takes her station where she is most likely to intercept her quarry and need travel only a short distance at a quickened pace to reach a good position for launching her torpedoes on their grim



THE "K-1," BUILT IN 1913

One of a group of eight identical boats each with a surface displacement of 392 tons and a submerged displacement of 521 tons. They were designed for a surface speed of 14.1 knots and a submerged speed of 10.6 knots. Some of these vessels saw active service in patroling the waters around the Azores during the final year of the World War. Although not intended for distant service, they kept their stations during very rough weather, but were deficient in habitability.


WATER BALLAST
SUPERSTRUCTURE
LIGHT WATER LINE
PRESSURE HULL
SHIP-SHAPE OUTER HULL SEALED AT SURFACE
CENTRAL BALLAST TANK
GERMAN DESIGN
RESERVE BUOYANCY 21%
SUPERSTRUCTURE SEALED IN SURFACE TRIM BUT FILLED WITH WATER BALLAST FOR SUBMERGED TRIM
WATER LINE SURFACE TRIM
WATER BALLAS
CYLINDRICAL MAIN PRESSURE HULL
OUTER HULL
DOUBLE HULL FOR 1/3 OF LENGTH, WITH PARTIAL DOUBLE HULL AT ENDS
ITALIAN TYPE OF LARGE DISPLACEMENT AND LARGE SURFACE BUOYANCY-----
CONNING TOWER
SUPERSTRUCTURE NOT WATERTIGHT
WATER LINE
PRESSURE HULL
BALLAST TANK
STORAGE BATTERIES ETC.
OUTER HULL
LATEST U.S. NAVY FLEET TYPE - WITH 38% RESERVE BUOYANCY

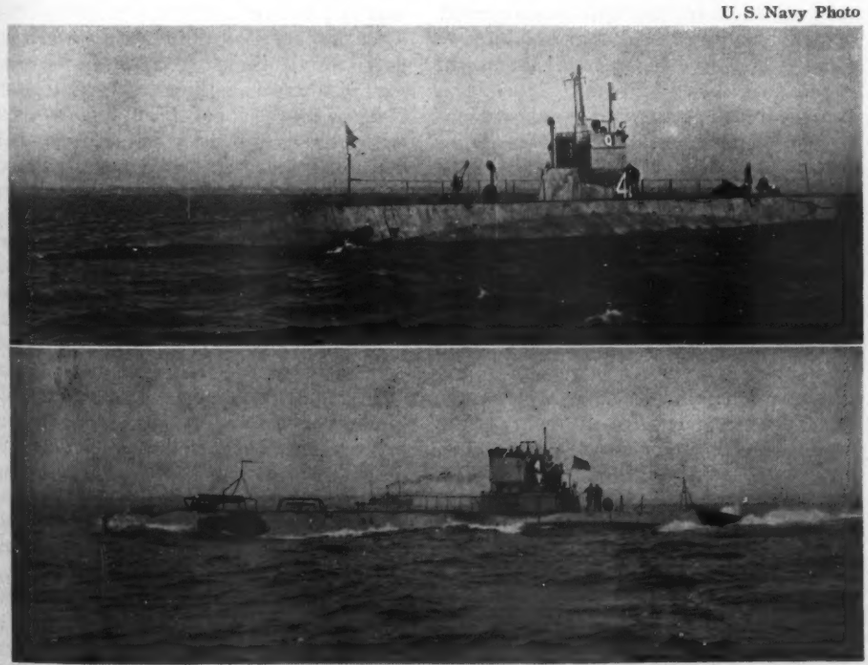
VARIATIONS IN HULL DESIGN

The six cross sections illustrate the ways in which different designers have combined pressure-resisting hulls with superstructures and outer hulls in an endeavor to give their submarines surface buoyancy for seaworthiness and ballast tanks that would virtually neutralize the surface buoyancy so that the craft could be submerged while underway and susceptible of underwater control while traveling at the lowest practicable speeds. In general, the difference between surface displacement and submerged displacement has increased in order to give the vessels a relatively large reserve of buoyancy when at the surface for the purpose of improving seaworthiness and the making of good speed. Seaworthiness has at the same time contributed to habitability, which was much to be desired because of the uncomfortable and exhausting conditions to which the men were exposed for a good deal of the time in the earlier submarines. The drawings all show the underwater boats at the surface, and the cross hatching indicates areas that are flooded when the submarines are submerged.

journey. Concealment is the prime purpose of the vessel at all times when in the neighborhood of an enemy; and with only one or more of her periscopes rising above the waves, her range of vision is ample for doing scouting work or picket duty for a coöperating surface battle fleet hidden below the horizon. The periscope of today is a far more effective observing instrument than that of 1918. Some boats have periscopes for watching the sky; and they also have optical range finders that make it far easier for the commanding officer to get his bearings upon an enemy craft before discharging torpedoes. Furthermore, the latter weapons have higher speeds, larger explosive charges, and run straighter than those of twenty years ago.

The latest of our submarines are provided with radios of long range. The Navy Department, in urging new engines for the *Narwhal* and the *Nautilus*, pointed out that these vessels, because of their notable seaworthiness and great offensive powers, would be valuable as squadron flagships and that the squadron commanders would then have additional personnel who would be mainly active in communication service and engaged in guarding the radio circuits necessary for wartime operations or in carrying out fleet problems. The usual complement of each of these submarine cruisers is seven officers and 62 enlisted men. Each boat has six torpedo tubes, with a reserve of several torpedoes for each tube, and carries two 6-inch rapid-fire guns. However, this battery may be changed so as to provide a number of anti-aircraft rifles of lesser caliber.

U. S. Navy Photo

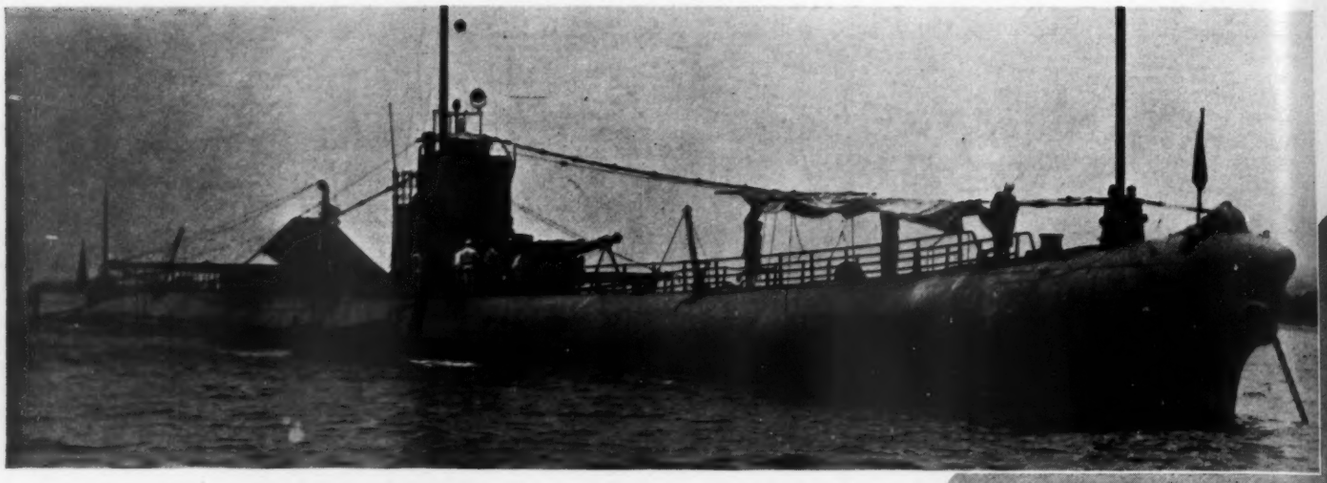


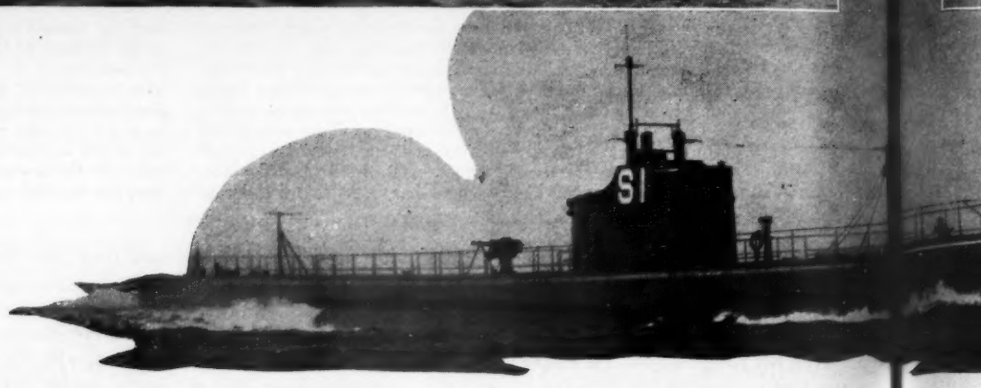
BOATS OF THE WORLD-WAR PERIOD

In the upper picture is one of our division of "L" boats that was based on Bantry Bay, Ireland, during the World War for patrol duty. At the bottom is shown the "R-4" on a speed run at the surface. She was commissioned in 1919 and, like all her somewhat numerous class, represented a further development of our underwater flotilla. The surface displacement is 569 tons and the submerged displacement is 680 tons; surface speed, 13.5 knots; submerged speed, 10.5 knots; armament, four torpedo tubes and a 3-inch, 50-caliber rapid-fire deck gun; complement, six officers and 24 enlisted men.

The deck guns of our underwater craft, according to official tables, range in caliber from 3 to 6 inches. But it is noticeable that the later vessels are armed well-nigh exclusively with 3-inch anti-aircraft rifles so that, if caught at the surface, they will be able to hold at bay airplanes that might sweep their decks with machine-gun fire or attack them with the far more deadly bombs with which they are now equipped. No matter what may be its enemy, the submarine's ultimate security lies in getting underwater where she will be unseen and less likely to be hit by shell or depth bomb. And her escape from attack will depend upon the quickness with which she submerges and gets away from the point where she was last visible. The success of this maneuver is contingent upon the rapidity with which she fills her ballast tanks and disappears below the surface of the sea.

Taking three different groups of our outstanding submarines of today, it will be seen that the difference between their surface and their submerged displacements





ranges from 25 to 50.6 per cent. This difference is known as reserve buoyancy—that is, the measure of buoyancy at the surface which contributes to seaworthiness but which must be neutralized by taking in water ballast to put the boat in condition for diving. For example, the *Barracuda* displaces 2,000 tons when running on the surface in cruising trim and 2,506 tons when operating underwater. To get beneath the waves quickly so that she can escape the gunfire of an approaching 35-knot destroyer, she has to take into her main and auxiliary ballast tanks within a minute substantially 506 tons of sea water and, what is more, fill those tanks so that there will be no surging to disturb the longitudinal balance of the craft when going either downward or upward during a submerged run.

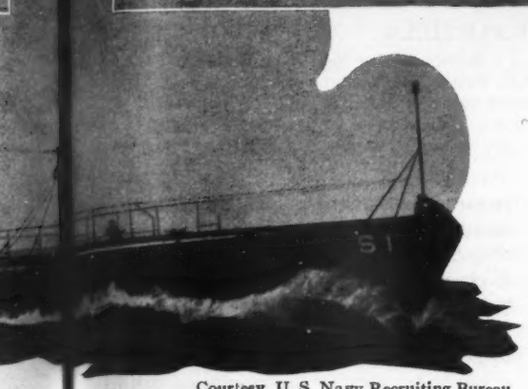
When the main and auxiliary tanks are taking in water ballast, the inflowing water forces out the air that is in them when the vessel is at the surface; and later, when she returns to the surface, the water is blown out with the aid of compressed air. Also, as a safety precaution, the tanks can be freed of their ballast with compressed air at any operable depth if something goes wrong and the submarine otherwise cannot be returned to the surface. But these ballast tanks do not carry all the water admitted to the craft to make her ready for diving.

Forward and aft there are trimming tanks that restore the boat to an even keel, just like the shifting of the opposite weights on a seesaw. The vessel must be nicely balanced in this respect so that she will be promptly responsive to the movements of her stern diving rudders and her bow diving planes. Then there are one or more tanks in midlength for the final adjustment of the ballast to reduce the submarine's buoyancy to the desired reserve of only a few hundred pounds. It is against this small impulse to float surfaceward that the craft is driven underwater through the joint action of her propellers and her diving rudders. Similarly, when all goes well, the boat is brought again to the surface without discharging water ballast, unless the intention is to restore her to surface trim and oil-engine propulsion. All the tanks mentioned can be emptied at any depth with compressed air.

In addition to the tanks enumerated, there are compensating tanks to which sea water is admitted to make up for weight lost through the consumption of fuel, food, changes in the number of men aboard, the discharge of ammunition, the firing of torpedoes, etc. The latter tanks are located in the vessel as close as practicable to the positions occupied by those supplies and weapons, and most of them can be freed of their water ballast with compressed air. As oil is expended from the fuel tanks, an equal volume of water is allowed to flow into them; and, if need be, the oil tanks can be emptied, one by one, with compressed air to give the submarine buoyancy to save her and her people or to aid in lightening her during salvage operations. But when water compensates for fuel used, the difference in the specific gravities of the two fluids must be taken into account in the final adjustment of the craft's buoyancy when making ready for diving. Again, the final-adjustment tank or tanks have to offset, by expelling or admitting water, any increase in weight due to leakage or to a change in the density of the water in which the vessel may be operating. Sea water is about 3 per cent heavier than fresh water; and submerged a submarine displaces the same volume in either. Therefore more ballast has to be taken aboard in sea water to compensate for its greater buoyancy, and, conversely, water ballast must be expelled to offset the lesser buoyancy of the lighter fresh water. This illustrates the nicety with which a boat of this type has to be adjusted for or during an underwater run.

In the case of one of our submarines engaged in peacetime maneuvers in the lower part of Chesapeake Bay and traveling submerged, it was found that the vessel was not properly responsive to her diving rudders unless several hundred pounds of water ballast was admitted to her compensating tank every few miles as she headed seaward. When she was out in the open ocean she had 2,000 pounds more ballast in her than when she started on her run in the less dense waters of the lower bay. Correspondingly, on her return trip, after passing beyond the Capes of the Chesapeake, it was necessary to blow on an average 175 pounds of water ballast with every mile of advance.

But the wartime experience of the U. S. *AL-4* probably offers the most thrilling example of what can happen to a submarine when, instead of a small reserve of buoyancy, she develops a correspondingly small negative buoyancy. That craft, one May morning in 1918, was operating about 30 miles off the coast of England as a listening patrol and running in a smooth sea at a depth of about 35 feet. While underway she responded promptly to her diving rudders, but the officer on duty noticed that the boat tended to sink when she was halted to facilitate listening for the propeller beats of any invisible vessel. That indicated that she was slightly unbalanced and had some negative buoyancy. Steps were immediately



Courtesy, U. S. Navy Recruiting Bureau

MODERN U.S. SUBMARINES

The "Barracuda," (upper left) is 341.5 feet long, and has a surface displacement of 2,000 tons and a submerged displacement of 2,506 tons. She is equipped with six torpedo tubes, mounts a 5-inch rapid-fire rifle, and has a complement of 87 officers and enlisted men. She was designed for a surface speed of 19 knots and a submerged speed of 8 knots, and is of a large sea-going type that is intended to operate with the battle fleet. The "Argonaut," the first of our mine-laying underwater boats, is shown above. She is 381 feet long and has a surface displacement of 2,710 tons and a submerged displacement of 4,080 tons. The two guns visible are 6-inch rapid-fire rifles. She has four tubes for the discharge of 21 torpedoes and carries 60 mines. Her personnel numbers 89, officers and enlisted men. This large vessel can keep the sea for about 90 days and has ample speed to work with the battle fleet far from our shores. The "Salmon," at the left, is one of a group of six identical submarines of the fleet type that was recently placed in commission. She has an over-all length of 310 feet, a surface displacement of 1,450 tons, and a submerged displacement of about 2,200 tons. This class can make a speed of 20 knots when running on the surface. Each boat is designed to carry at least one 3-inch rapid-fire rifle, perhaps one or more machine guns for repelling aircraft, and has eight torpedo tubes, placed both at the bow and stern, large enough to discharge 21-inch torpedoes.

taken to adjust her trim; and the order was given to blow 300 pounds of water overboard from an adjusting tank. Unfortunately, an inexperienced hand, instead of working the proper valve, opened a Kingston that admitted more ballast. When the mistake was discovered, and the submarine continued to settle, the officer in charge ordered "Up rudders and full speed ahead"; but, even so, the *AL-4* dropped bottomward and came to a halt only after she struck the muddy sea bed where the depth gauge registered 294 feet!

We need not dwell upon the gravity of the situation, nor how, for more than an hour, the boat remained fast and the outlook for escape dimmed. In the end, the blowing of certain of the tanks broke the grip of the mud, and the bow lifted and started surfaceward—the craft pointing upward at an angle of 50° while climbing rapidly under the full drive of her electric motors. The middle and after main ballast tanks, designed for a maximum pressure of 75 pounds, were emptied with air at 127 pounds; and the forward trimming tank, intended to withstand a pressure of 90 pounds, was freed of its water with air at 140 pounds! In his war diary, the commanding officer, Lieut. Lewis Hancock, Jr., U.S.N., made this notation: "Every man stood by his station in as calm and efficient a way as if an ordinary drill were being conducted." The chart showed a depth of 300 feet where the *AL-4* went to the bottom, or 60 feet deeper than the water in which the U.S. Submarine *Squalus* sank and from which she was salvaged last summer.

In some of the U-boats that saw service during the World War, the ballast tanks were hooked up with the compressors, acting *pro tem* as vacuum pumps, so that a partial vacuum could be created in the tanks before submerging. When the Kingstons were opened to flood them, the sea water rushed in through the valves and filled the tanks much faster than would have been the case with the water entering at the existing hydrostatic head and expelling air at atmospheric pressure. In that way precious seconds were saved, and the U-boats were able to escape from gunfire and to dive quickly to a depth where they could not be rammed.

The very small percentage—a few hundred pounds—of reserve buoyancy retained by a submarine when in proper diving trim makes it possible to handle her easily with her stern diving rudders and her bow planes. She can be driven under from the surface when inclined less than 3°, and she can be taken down to her maximum safe depth, or held virtually level, and then brought up to the surface merely by changing the angles of her rudders and planes, without any discharge of water ballast. Usually, both the stern rudders and the bow planes are shifted at the same time to apply pressure of suitable moment at each end to tip the bow up or down; but the sensitiveness of response and the trim of the craft may be such that one set of planes will suffice to maneuver her vertically underwater. In July of 1918, the U. S. Submarine *E-2* was on patrol duty off our Atlantic seaboard in the vicinity of Cape Hatteras. On the day in question she ran submerged continuously for seventeen hours at a speed of 4 knots. All that time she was kept under perfect control by maneuvering her bow rudders alone, and she was balanced so nicely that no change was made the while in her water ballast.

People unfamiliar with the complicated get-up of a modern submarine are unaware of the precision required in designing and distributing the diversified weights of such a boat that she will have a proper measure of stability at the surface or submerged, or when passing the critical stage incident to shifting from one to the other operating condition. The designer may exercise the utmost care; but unexpected weight may be added somewhere during construction, or, when commissioned later on, supplemental apparatus or other contrivances may be mistakenly placed aboard in the belief that they will be of value. In active service, successive coats of paint may discount the originally planned surface buoyancy! All these changes are likely to make it difficult if not impossible to give the craft her necessary reserve of buoyancy when fully laden and ready to go to sea to participate in war or peacetime maneuvers. Every trespassing pound of excess weight entails a sacrifice in food, fuel, lubricating oil, or other indispensable supplies that have a bearing on the vessel's maximum military usefulness.

Besides blowing water ballast from the various tanks under different conditions of operation, compressed air is used to eject the torpedoes from the tubes when launching them at their targets. Air at high pressure also provides these weapons with the primary source of propulsive power after they leave the submarine. The torpedoes are charged with air at a pressure of 2,800 pounds per square inch. Many of the large and important valves and other apparatus in an underwater boat are operated hydraulically, and the water pressure for these purposes is maintained in accumulators against a cushion of air at 1,500 pounds pressure. Her sanitary tanks are drained outboard under the impulse of compressed air at 200 pounds per square inch; and air pressure is applied to the fresh-water supply system to assure circulation to the various points throughout the interior of the craft.

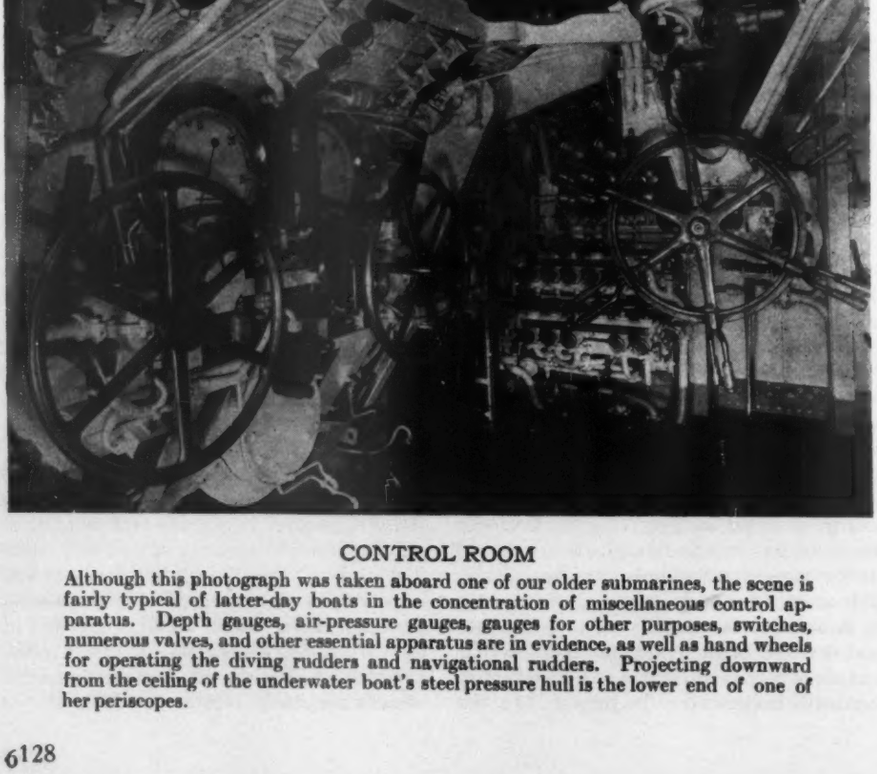
In addition to these services, compressed air ejects the smoke bombs from the projectors that carry those missiles to the surface from any depth. The bombs give off a cloud of smoke in the daytime and are luminous at night, and make it possible to locate a submarine in distress and resting on the sea bed. It is used to start the Diesel engines that drive all our submarines when they are running light or in surface trim; and, finally, it may be drawn on for life-saving purposes by partly placing the interior of a sunken boat under compensating air pressure so that escape hatches can be opened against the pressure of the sea and outlets thus afforded for the men to leave the vessel and float to the surface. To do that, the men put on "escape lungs," devised for the service, which they first fill with oxygen stored under pressure in flasks placed in different parts of the craft where they are readily available.

Courtesy, U. S. Navy Recruiting Bureau

SUBMARINE FLOTILLA

Six submergible craft and a mother ship in a harbor during fleet operations in the Caribbean Sea. The mother ship constitutes a repair base, a source of supplies, and a place where the crews of a submarine division can relax after a period of confining work at sea.

Every up-to-date submarine in the U. S. Navy is equipped with a number of high-pressure compressors that are especially designed for the work; and the air is stored in banks or groups of steel bottles which have a combined capacity ample to meet the requirements of the particular vessel. The flasks are located variously in the craft, wherever space permits; and the practice is to charge most of them at high pressure and to deliver the air to several manifolds from which it can be distributed by means of interposed reduction valves to the points of application and at the pressures desired. Where compressed air is used to empty tanks, it has a number of advantages over pumping: the air lines are of smaller diameter than corresponding piping for pump connections, and this makes for a saving in space and weight. After any extended operation submerged, the underwater torpedo boat has to return to the surface to have her storage batteries recharged by the generators, and at the same time her compressors are run to recharge the air flasks. This may take several hours, depending, of course, upon how long the submarine has remained submerged and how much of her stored electricity and of her reserve of compressed air she has been obliged to draw upon.



CONTROL ROOM

Although this photograph was taken aboard one of our older submarines, the scene is fairly typical of latter-day boats in the concentration of miscellaneous control apparatus. Depth gauges, air-pressure gauges, gauges for other purposes, switches, numerous valves, and other essential apparatus are in evidence, as well as hand wheels for operating the diving rudders and navigational rudders. Projecting downward from the ceiling of the underwater boat's steel pressure hull is the lower end of one of her periscopes.

In the earlier days of our submarines, duty aboard any of them, particularly in rough weather, was akin to the traditional "dog's life"; but our latter-day vessels are vastly improved in the matters of their accommodations, habitability, means for storing and preparing food, and access to the open air when at the surface in all but the stormiest of seas. Notwithstanding these betterments, the underwater boat, because of her characteristic get-up and the nature of the work expected of her, can best be handled by an especially trained but essentially youthful personnel boasting abundant vigor and plenty of nerve, and able to meet hardships and face grave risks undismayed. The men of our submarine service have amply demonstrated their fitness in these respects; and it is upon the officers and crews that the endurance and effectiveness of these fighting craft ultimately rest.

Steam Condensers

PART 2

A. D. Kann

Effect of Design Factors on Ratio

BY MEANS of curves such as Figures 5, 6, and 7 it is possible to show what effect individual variations in tube diameter, length of water travel, or velocity have on ratio. But as the magnitude of the change in ratio depends on the magnitude of each of the other fixed factors, it is impracticable to use these curves to obtain actual numerical answers. The important point is to visualize just how ratio is affected by any change in each of the several factors, and to note the rapidity with which the ratio is affected. For instance, if tube diameter is increased and length and velocity are held constant, the ratio drops rapidly. On the other hand, if length of water travel is increased and tube diameter and velocity are constant, the ratio rises rapidly at first but more and more slowly as length is increased. Again, if velocity is increased and tube diameter and length are fixed, the ratio drops off gradually.

These definite effects enable us to approach the problem of condenser design or selection rationally, and permit us to vary one or more factors in such a way as to produce the desired result. Naturally, there are other considerations related to each of the factors that modify or limit the extent of the variation. For example, too great a length or too high a velocity, or both, cause too much of a pressure drop. This can be offset by utilizing a tube of larger diameter. However, larger diameter, in turn, involves the use of more circulating water per unit of surface to obtain the desired velocity, and tends to limit large tube sizes to large condensers.

In practice, the useful range of the R factors is about as follows:

Tube diameter, outside, 5/8 to 1 inch.
Length of water travel, 12 to 48 feet.
Velocity, 4 to 8 feet per second.

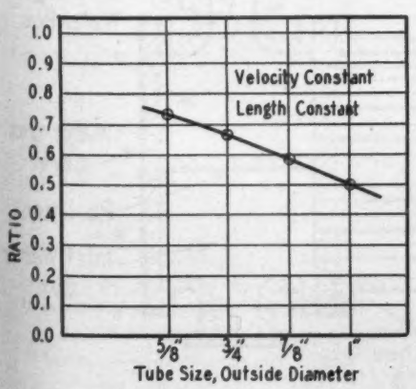


Figure 5

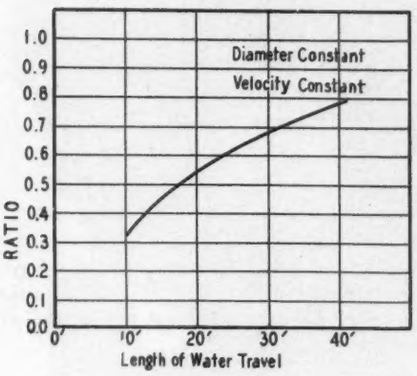


Figure 6

This digression into a rather elaborate discussion of ratio has been made in order to emphasize that ratio is a "built-in" quality in a surface-type heater or condenser of any stated water velocity. As velocity in a finished shell-and-tube unit depends only upon the amount of water forced through the unit, it follows that the ratio is fixed for any given quantity of circulating water.

It is necessary, for a more complete analysis of ratio, to take account of the effect of "efficiency" on the performance of a heat exchanger. When used in this sense, efficiency is the heat-transfer rate actually obtained, compared with the expected rate. In practice, the expected rate may be depreciated by various parasitic influences, of which air-blanketing and dirt—tube fouling—are common and important. The magnitude of the change in ratio is always relatively less than the per cent change in heat-transfer efficiency. Heat-transfer rates higher than those estimated may also be realized, with resulting lesser increases in the value of R.

Size of Unit

Returning to Figure 4, which is shown on page 6108 in the preceding issue, let us assign a value to the built-in ratio, say 0.5, with a water velocity of 6 feet per second. It is now possible to find out how big such a unit must be to heat a given quantity of water; how much the water will be heated; how much steam will be condensed; and how much condensate there will be—all based on atmospheric pressure in the shell.

By designing the unit for an 0.5 ratio, we have decided that we want to heat the water half way to the theoretical maximum:

EXAMPLE 1

Steam temperature, atmospheric	= 212°F.
Cold-water temperature, inlet	= 72°
Initial temperature difference	140°

$TD \times R = TR = 140 \times 0.5 = 70°$

Should we want to heat 1,000 gpm. from 72° to 142°, the heat to be added to the water would be:

$1000 \times 8.33 \times 60 \times 70 = 35{,}000{,}000$ *Btu./hr.*

In *Cameron Hydraulic Data*, page 66, the latent heat of steam at atmospheric pressure is given as 970 Btu. per pound. Hence

$$\frac{35{,}000{,}000}{970} = 36100 \text{ } lb./hr. \text{ } of \text{ } steam$$

to be supplied for heating the water. This steam will be condensed; and we will drain out of the heater 36,100 pounds of condensate—distilled water—per hour, or 72.2 gpm.

Referring to the available design data, we find that the over-all coefficient of heat transfer for steam to water through brass tubes of 3/4-inch diameter and with a water velocity of 6 feet per second is 580 Btu. per square foot per degree of (Fahrenheit) mean temperature difference per hour. (The latter figure is based on an average temperature of the water film, say 132°.) This coefficient, experience has shown, can be realized in commercial practice with commercially clean tube surfaces.

We now have to figure the logarithmic mean temperature difference (coefficients of heat transfer are almost invariably related to *LMTD*, which is the closest criterion of the actual average temperature difference in a typical shell-and-tube exchanger). The formula for a steam-to-water heater or condenser is:

$$LMTD = \frac{TR}{\log_e \frac{TD}{Approach}} \qquad (4)$$

In the present example

$TD = 140°$
$TR = TD \times R = 140 \times 0.5 = 70°$
$Approach = TD - TR = 140 - 70 = 70°$

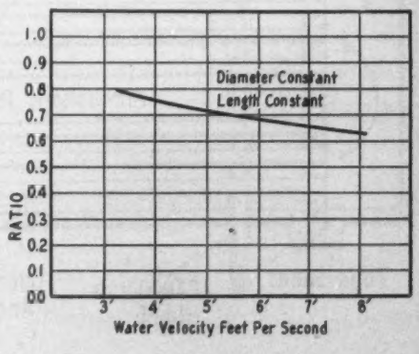
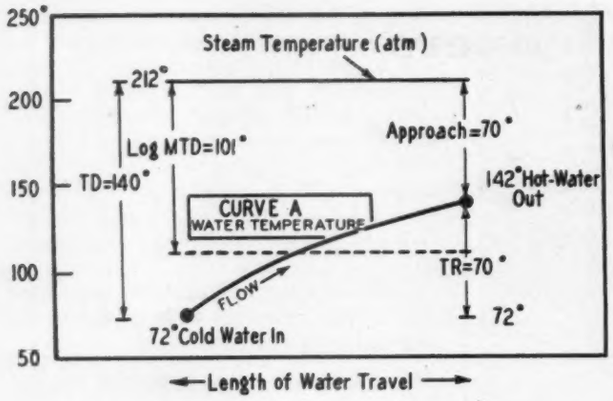


Figure 7



TEMPERATURE DISTRIBUTION IN A SHELL-AND-TUBE WATER HEATER

Figure 8

Figure 8 shows the manner in which temperature is distributed throughout the effective length of a heater, and affords an idea of the mean temperature difference. The *LMTD* is used because, mathematically, the actual form of Curve "A" approximates a logarithmic function. Therefore

$$LMTD = \frac{70}{\log_e \frac{140}{70}} = \frac{70}{\log_e 2} = \frac{70}{2.3 \log_{10} 2}$$

$$= \frac{70}{2.3 \times 0.301} = \frac{70}{0.692} = 101°$$

and the required heat-exchange surface will be:

$$Surf. = \frac{Load\ (Btu./hr.)}{Coef. \times LMTD} \qquad (5)$$

$$= \frac{35{,}000{,}000}{580 \times 101} = 598\ sq.\ ft.$$

Having decided on tubes of ¾-inch outside diameter, we find upon calculation that there is an external area of 0.1963 square foot per linear foot of length. We also find that with a velocity of 1 foot per second and with a wall thickness of No. 18 Bwg. (Birmingham wire gauge), each tube will handle 1.04 gpm. At a velocity of 6 foot-seconds each will handle 6.24 gpm. To take care of 1,000 gpm. at 6 feet per second we require

$$\frac{1000}{6.24} = 160\ tubes\ (approximate).$$

The length of each tube will therefore be

$$\frac{598}{160 \times 0.1963} = 19\ ft.$$

It is practicable to build a shell with 19 feet between the tube sheets. However, space limitations might prevent the use of a unit 22 or 23 feet long over-all. In such an event, the same effective length could be obtained by using twice the number of tubes, only 9 feet 6 inches long, and circulating the water first through half of them and then through the remaining tubes. In other words, there would still be a total length of water travel of 19 feet at a velocity of 6 feet per second. This would be a 2-pass shell and would contain 320 tubes arranged in two banks, as shown in Figure 9.

A heater of this kind should do just what is expected of it under the operating conditions for which it is designed. The steam will flow in at the top and the condensate out at the bottom. Air in the steam will be forced out of the open drain with the condensate, because air is heavier than steam and will be crowded to the bottom of the shell. The device is simple and effective. No gadgets, no accessories are needed, provided of course it is to be operated only at a steady, uniform rate. But it may be seen that steady, uniform conditions, desirable as they might be, are seldom attainable. It is therefore necessary to see what will happen when the expected conditions are upset.

Effect of Higher Ratio

Although it might be possible to regulate the flow of both steam and water, and to deliver them at a constant rate of 36,100 lb./hr. and at 1,000 gpm., respectively, there is no certainty that the temperature of the entering water will always be 72° and that the tube surfaces will remain as clean as they were when operations started. The device that has been developed is not expected to fail, and will heat water even should one or more of the conditions for which it is designed be altered; but we do want to know what changes in character of performance will follow modifications of the initial set-up. A change in the quantity of water will produce reactions that are impressive. Let us assume that the steam flow is constant—that it is metered through an orifice or other control device. The open drain in the shell results in atmospheric pressure at all times within the shell. Suppose the *GPM* falls to 900. In that case the velocity will drop to

$$6 \times \frac{900}{1000}\ or\ 5.4\ ft./sec.$$

This means that ratio will rise slightly. The coefficient of heat transfer will fall somewhat. The tube (transfer) surface remains constant. Because *R* rises, *TR* will rise, leaving *TD* unchanged. Although both *TR* and *R* increase, inspection of Figure 8 will show that with increased *TR*

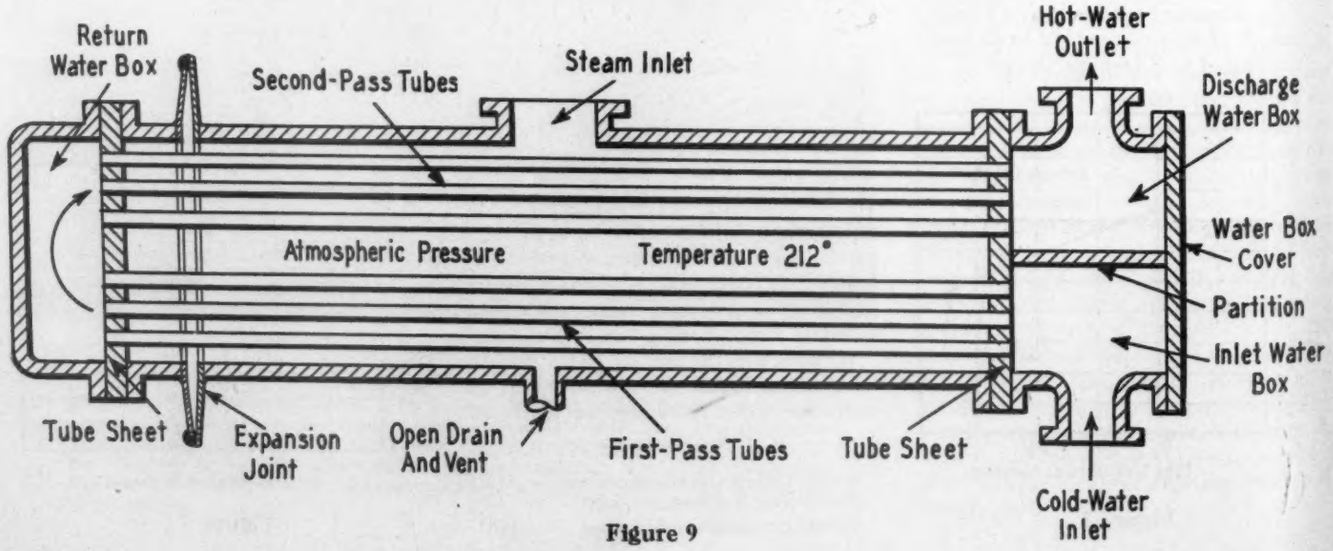


Figure 9

the *LMTD* must necessarily decrease, because the "approach" will be smaller and the average level of the water temperature line will be raised. This relationship can be developed mathematically, and will produce a new value of

$LMTD = 99.5°F.$*

The Btu. load that can be handled equals:

$Surf. \times Coef. \times LMTD$

$or\ Load = 598 \times 550 \times 99.5°$

$= 32{,}730{,}000\ Btu./hr.$

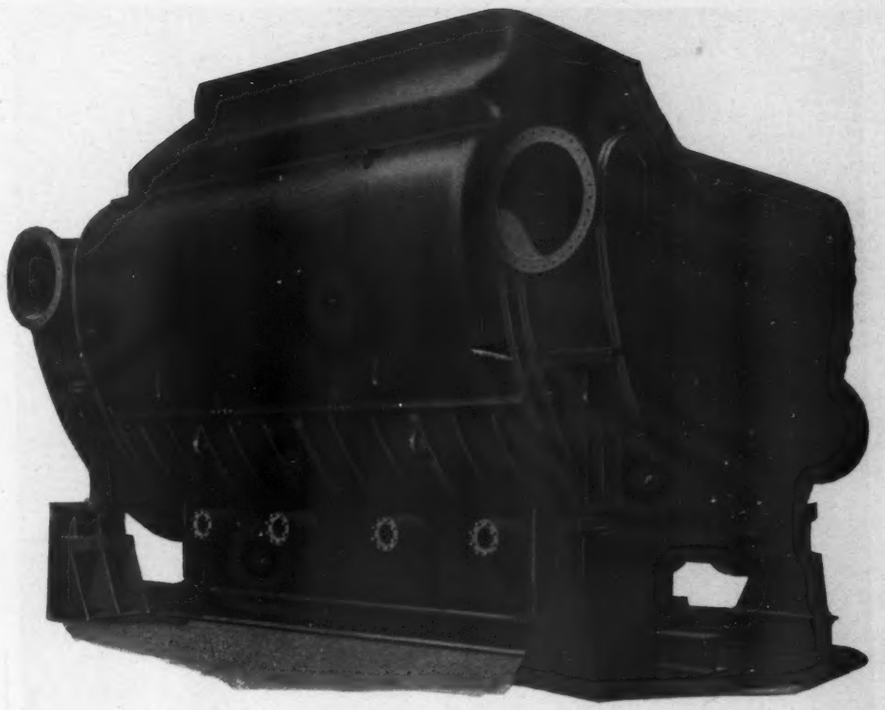
This figure is about 6 per cent lower than the original load of 35,000,000 Btu./hr.

It is apparent that by reducing the *GPM*, with no other change, we have decreased the capacity of the heater. This emphasizes the law that reduced water flow always involves lower capacity, and *vice versa*, in a unit already designed and built, provided no other alteration in operating conditions is made.

With a 6 per cent reduction in heat-transfer capacity, it is evident that 6 per cent of the steam flowing into the shell will not be condensed but will flow through the shell, out through the open drain, and be wasted. Obviously, this simple vent will not be satisfactory, because we must expect variations in operating conditions and do not want steam to be wasted. Conversely, should the flow of water be increased, leaving all other conditions alone, the capacity of the unit would be increased, and the original steam flow would not suffice to do all the heating of which the unit is capable. This means that all the steam may be condensed before it reaches the lowest tubes in the shell. These tubes will then be automatically air-blanketed, and their usefulness as heat-exchange surfaces will be nullified. The greater flow of water will be heated to the full extent permitted by the available latent heat in the full flow of entering steam. That is, 35,000,000 Btu. per hour will be absorbed by the water, but the unit will not be utilized 100 per cent. The unused capacity could be taken up by increasing the steam flow, if additional steam is available.

From these reactions it is seen that a shell-and-tube exchanger, such as a water heater or condenser, has no fixed capacity in terms of steam flow, or Btu. transferred, but is, in reality, extremely flexible as to actual capacity. This fact should always be kept in mind, in view of the frequent assumption on the part of purchasers that a shell-and-tube exchanger is no good unless it is big enough for the ultimate peak load that might be imposed upon it. It is rare, indeed, when a water heater or condenser cannot be made to do a certain job if it is anywhere near large enough, if some variation in pressure and/or temperature is permissible. In technical work, involving accurate control of pressure or temperature, there is justification for great care in selecting an exchanger so that it will be of ample size to meet the most severe operating conditions and the maximum load.

As a further example of the effect of high ratio, it might be of interest to go back to Example 1 and the problem we have worked out to see how much bigger and, incidentally, more expensive the heater would have been if it had been designed for a ratio of 0.75 rather than for one of 0.5. For the sake of simplicity it can be assumed that the water velocity and the tube diameter will not be changed. The heat transfer coefficient will therefore not be affected. With these limitations established, and from the discussion of Figures 5, 6, and 7, it becomes evident that only the total tube length can be changed to obtain the higher ratio and that it will be increased. Repeating the former procedure, we have:



SINGLE-PASS CONDENSER

An Ingersoll-Rand single-pass condenser that serves a 55,000-kw. turbine. The tube bank is divided into four vertical sections by tube support plates. The air outlets, one from each of these sections, are shown. The main shell is thus subdivided into four small condensers of short tube length. Each section is independently controlled so that its surface operates at maximum efficiency.

*Original velocity = 6 ft./sec.
New velocity = 5.4 ft./sec.
Original coefficient = 580Btu./sq.ft./deg./hr.
New coefficient = 550 Btu./sq. ft./deg./hr.

$$Surf. = \frac{Load}{Coef. \times LMTD} = \frac{GPM \times TR \times 500}{\dfrac{Coef. \times TR}{\log_e \dfrac{TD}{Appr.}}}$$

$$= \frac{\log_e \dfrac{TD}{Appr.} \times GPM \times 500}{Coef.}$$

$$or\ \log_e \frac{TD}{Appr.} = \frac{Surf. \times Coef.}{GPM \times 500}$$

$$= \frac{598 \times 550}{900 \times 500} = 0.731$$

$$\log_{10} \frac{TD}{Appr.} = \frac{0.731}{2.3} = 0.318$$

$$\frac{TD}{Appr.} = 2.08$$

$$TD = 140$$

Therefore:

$$Appr. = \frac{140}{2.08} = 67.3°$$

$$TR = TD - Appr. = 140 - 67.3 = 72.7°$$

$$LMTD = \frac{72.7}{\dfrac{TD}{\log_e Appr.}} = \frac{72.7}{0.731} = 99.5°$$

EXAMPLE 2

Steam temperature, atmospheric	= 212°F.
Cold-water temperature	= 72°
Initial temperature difference	140°

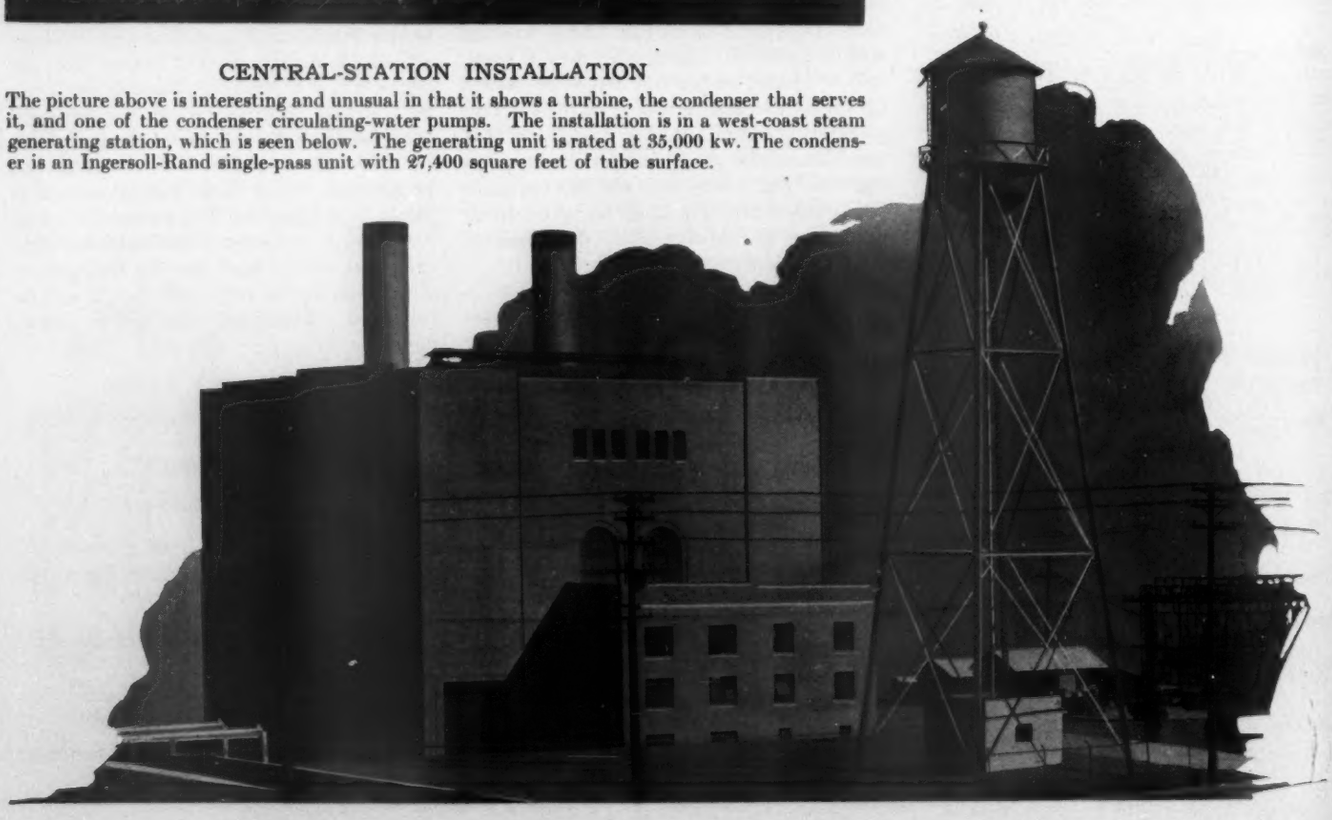
$TD \times R = TR = 140 \times 0.75 = 105°$

In this case, by heating 1,000 gpm. of 72° water to 177°, the heat added to the water will be:

$1000 \times 8.33 \times 60 \times 105 = 52{,}500{,}000\ Btu./hr.$

$\frac{52{,}500{,}000}{970} = 54{,}150\ lb./hr.\ of\ steam.$

The new elements in the *LMTD* formula will be:



CENTRAL-STATION INSTALLATION

The picture above is interesting and unusual in that it shows a turbine, the condenser that serves it, and one of the condenser circulating-water pumps. The installation is in a west-coast steam generating station, which is seen below. The generating unit is rated at 35,000 kw. The condenser is an Ingersoll-Rand single-pass unit with 27,400 square feet of tube surface.

$TD = 140°$
$TR = 105°$
$Approach = 35°$

$$LMTD = \frac{105}{\log_e \frac{140}{35}} = \frac{105}{\log_e 4} = \frac{105}{2.3 \log_{10} 4}$$

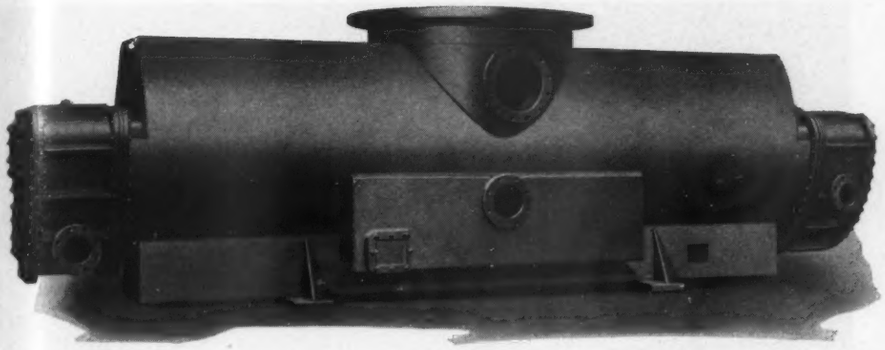
$$= \frac{105}{2.3 \times 0.602} = \frac{105}{1.384} = 75.8° \text{ (24\% } lower\text{)}$$

The required heat-exchange surface (with velocity and coefficient unchanged) will then be:

$$Surf. = \frac{52{,}500{,}000}{580 \times 75.8} = 1195 \text{ } sq.\ ft.$$

This is double the area previously determined. Obviously, according to the new calculation, the unit transfers 50 per cent more heat in a given length of time; but, prorated on the basis of equal transfer of heat, it will be apparent that 797 square feet, or one-third more surface, will have to be employed to exchange the same quantity of heat as previously but with a ratio of 0.75 instead of 0.5. It is reasonable that the cost of the apparatus will be in proportion to the size.

Returning to a consideration of the problem as one of heating water, we find that twice the surface is required to heat 1,000 gpm. through a 50 per cent greater range of temperature, although only 50 per cent more steam is needed to do the job. If first cost of the apparatus is to be taken into account, it must not be designed for a higher ratio than absolutely necessary. The total tube length for 1,000 gpm. can be determined as before:



TWO-PASS CONDENSER

A typical surface condenser with a steel-plate shell. It has 2,510 square feet of tube surface. Because it must operate with a widely varying quantity of water, it is arranged for either single- or 2-pass operation. The steam inlet is at the top.

$$\frac{1195}{160 \times 0.1963} = 38\ ft.$$

It will be observed that the tube length has doubled with the surface, as neither the *GPM* nor the velocity has been changed. However, the tube length would still be 38 feet for the new 0.75 ratio even if the unit had been built for the original total heat exchange and its surface had been increased only 33 per cent. For transferring 35,000,000 Btu. per hour, with a 105° rise in water temperature:

$$GPM = \frac{35{,}000{,}000}{105 \times 8.33 \times 60} = 667$$

At a velocity of 6 feet per second and with ¾-inch (outside diameter) tubes:

$$\frac{667}{1.04 \times 6} = 107\ tubes$$

$$Length = \frac{797}{107 \times 0.1963} = 38\ ft.$$

An exchanger of single-pass construction with tubes 38 feet long might serve, although the latter would exceed the usual commercial proportions. Or, we could use a 2-pass unit (Figure 9) with 19-foot tubes, or a 3-pass exchanger with tubes 12 feet 8 inches in length. It should not be necessary to go to 4-pass construction with tubes of 9 feet 6 inches, except for reasons of restricted space. It is a fact that high ratio not only increases the amount of heat-transfer surface required to do a specific job but, as can readily be realized, any multiplying of the number of water passes definitely tends to make the unit more complex.

Reverting to the vented atmospheric unit under discussion, we have noted that it is likely to be operating "off" the design point a great deal. When it is underloaded we do not want to waste steam, nor do we constantly want to regulate the steam flow either manually or by the use of some automatic throttling device. One thing that we can do is to close the shell; but we shall have to put on a relief valve to prevent overpressure. We can drain the condensate through a float-controlled trap or a loop seal if the internal shell pressure is never to exceed a few pounds gauge.

Air Venting

To vent air and other noncondensables from the shell, an air valve is needed. Every steam radiator has one unless it works as a part of a vacuum system. This device is available in many different forms. A simple type uses a thermostatic trap, as shown below in Figure 10. In this case the metal bellows *A* is filled with a volatile liquid which, upon vaporizing with rising temperature, exerts pressure and causes the bellows to expand. The latter carries a needle valve, *B*, that seats in orifice *C* when the bellows is expanded. Air from the bottom of the shell flowing through pipe *D* is rapidly air-cooled and reaches air trap *E* at a temperature substantially lower than that of steam— 212° or higher. After all the air has been bled off through *C*, steam will follow through *D* into *E*. Having a high latent heat, only a fraction of this steam will be condensed in *D* and *E* by air-cooling. As a consequence, *E* will soon be charged with steam at 212° or higher and the bellows will expand, closing orifice *C* and preventing any loss of steam so long as chamber *E* is filled with steam. While *C* is closed and *E* is full of steam, air will gather in the bottom of the shell, soon covering opening *O* and thus cutting off the supply of steam to trap *E*. The steam in *D* and *E* will then condense quickly, permitting cool air to fill *E*, whereupon the bellows will contract, opening *C* and allowing the air to escape.

By adding a device of the kind just described, the shell can be operated at any steam pressure higher than atmospheric and clear itself automatically of air. Now, should the load become light through some cause such as circulating less water, the excess steam trying to get into the shell will not be able to escape and be wasted. Pressure will build up in the shell until the condensing temperature of the steam will have been raised to a point at which there will be an increase in temperature difference which, in turn, will increase the transfer of heat to the water in the tubes. In short, the full capacity of the unit will be used by heating a smaller quantity of water to a higher degree.

Perhaps it is undesirable to let the water get too hot. Under those circumstances it is common practice to install a thermostat in the outgoing water line that will control a valve so as to throttle the steam supply and maintain a uniform outgoing temperature, letting the shell pressure go where it will as the load fluctuates. In any event, the air that accumulates will be removed whenever the shell pressure exceeds atmospheric.

The addition of an air valve has greatly increased the unit's flexibility; but, even so, we still have to provide some means whereby the air can be withdrawn from the shell whenever it is desirable to operate with less than atmospheric pressure. There may be several reasons for doing this. When we have included this feature we shall at last have a piece of equipment that may be regarded primarily as a condenser rather than a water heater. Water heaters are frequently operated under a vacuum for perfectly valid reasons, but the emphasis is on water heating. In the case of condensers, the emphasis is laid on the maintenance of a vacuum by condensing steam, which heats water.

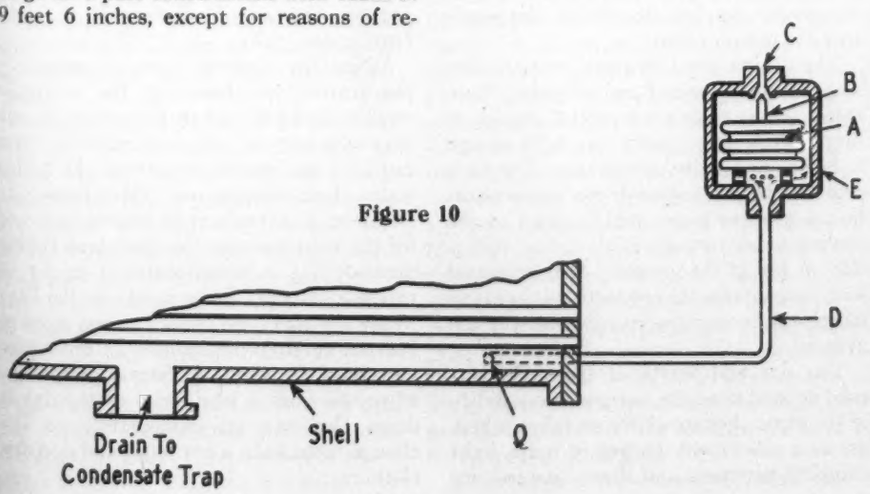


Figure 10

The third and concluding article in this series will appear in the May issue.

Pneumatic Tools Aid Tube Descaling

INSIDE A TOWER

At the top men are at work cleaning a tube bank with pneumatic hammers while water sprays down on them. This practice is permissible in warm climates. The scale that has been removed from the tubing is raked from the water pit in the base of the tower, as shown immediately above. By this method it is possible to reach tubes that formerly could not be descaled.

THE gasoline department of the Union Oil Company of California uses pneumatic tools to remove scale from the exterior surfaces of cooling and condensing coils. The method was developed in the Santa Fe Springs natural-gasoline plant and has been found to be superior in various respects to the manual operations that were formerly employed.

The coils that are cleaned are tubular pipes installed in the lower part of a water-cooling tower through which products and commodities are passed and subjected to a continuous spray of falling water to reduce their temperature. As the cooling water evaporates upon striking the hot pipes, a scale, commonly called "lime," is deposited on them, insulating them and retarding the exchange of heat. The rate of deposition depends upon the quantity of scale-forming minerals in the water and the length of time it is used without flushing the basin at the base of the tower. With certain kinds of water the film increases rapidly.

It has been the practice of many companies engaged in natural-gasoline manufacture to remove this accumulation of scale with light ball-peen hammers. Workmen enter the cooling tower, oftentimes with the circulating water cut off, and tap the pipes lightly to free them of scale. This method is effective so far as it can be carried out; but it is a slow, tedious process. It also reduces the output of the plant, as there is less exchange of heat while water is not falling over the pipes.

The construction of the cooling sections and the installation of cooling banks in relatively close quarters hinder the workmen and many times prevent them from reaching the areas with the largest accumulations of scale. As a result, the pipes that are most accessible are cleared of scale down to the bare metal, while those well down in the stacks, or those that are hidden by others, are never cleaned. Consequently, the full benefit of the water spray is not obtained.

The Union Oil Company removes the scale with Ingersoll-Rand chipping hammers. These tools are powerful enough to break off the film quickly, yet light enough to be handled easily by one man. The air is provided by gas-engine-driven compressors in the gasoline plant, and is piped to the cooling tower through a 2-inch line that is laid on top of the ground. It is equipped with take-offs for the connection of as many lengths of hose as are required for the job at hand.

The size and length of the chisel bits used depend upon the size and accessibility of the pipes. For small bronze tubes, which are as a rule closely packed in units, light chipping hammers and short bits are employed. For 2- and 3-inch pipes, which are generally stacked in vertical sections, the hammers are larger and the bits sufficiently long to permit a workman standing upon planking laid across the bank of coils to reach the lowest tier of pipes.

Several men are usually sent into the cooling tower at a time, all working in one bay so that the cleaning operation may be expedited. When the pipes are arranged so that any tube may be descaled easily, each man works alone; but when the assembly is such that it is difficult to get at the lower pipes, a second man, with a crowbar, springs them apart so that the hammerman can insert the bit.

When choosing heads for the bits, the size and type of the tubes are taken into consideration, but the shape of the heads is the same regardless of their size. Some experimenting had to be done before the most practical design could be found that would remove the scale successfully and at the same time not damage nor mar the outside surface of the pipes. The head is forged on the end of the bit and is in the form of a saddle. The skirt is rather narrow, the end being turned up slightly like a sled runner. No sharp edges are permitted on any part of the head, and those left when shaping it in the forge are either ground away or filed smooth to avoid cutting the pipes.

When the cooling tower is opened in preparation for descaling, the workmen wear a complete suit or slickers or merely over-alls: but, in any case, most of them put on a sou'wester to prevent the falling water from running over their faces. In Southern California it is seldom too cold for the men to enter the structure lightly dressed; but in other states it might be necessary to cut off the sprays in the bays where the pipes are being cleaned so as to prevent chilling, particularly in the colder months of the year. At Santa Fe Springs, when the work is completed or the day is done, the men go immediately to the change room, take a hot bath, and don dry clothing.

75 YEARS OF SERVICE

THIS year the asbestos industry is celebrating its diamond jubilee. Strictly speaking, this "silk of the mineral kingdom" has been used much longer than 75 years; but that is the age of the industry as we know it today. Actually, ancient peoples had lampwicks made of asbestos; and Marco Polo wrote of seeing it employed for various purposes in Siberia in the thirteenth century. However, modern industrial development has made this adaptable mineral the common servant of mankind that it is today.

Asbestos, like most of our minerals, is won from the ground with the aid of rock drills and blasting powder; and both its mining and refining have been developed to a high degree of efficiency. Although the United States is the largest consumer of asbestos, we produce only 4 or 5 per cent of our own requirements. Fortunately, our next door neighbor, Canada, has rich reserves of the mineral, and its mining is an important industry there. Venezuela, India, South Africa, and Cyprus also are large producers of asbestos.

Most of us know asbestos best for its insulating and heat-resisting qualities, and it is surprising to learn that it was so little known in this respect when James Watt developed the first practical steam engine that he turned to wooden strips as the most practical material available for conserving its heat.

Nowadays the applications of asbestos are legion. Motor cars could neither be properly started without asbestos clutch facings nor safely stopped without asbestos brake bands. By sheathing the roofs and sides of frame houses with shingles containing asbestos the structures can be rendered virtually immune to fire from without. Such shingles are now extensively employed; but they were unknown 35 years ago. Asbestos is of great importance to the electrical industry and to heating and power plants. Gloves made of it have long protected the hands of firemen and of many workers generally, and complete suits of it have made their appearance. In short, asbestos serves humanity in so many ways that it merits classification as an indispensable mineral.

WHERE WATCHFULNESS PAYS

IT IS recognized that well-run industrial plants pay careful attention to their compressed-air systems and, consequently, get the fullest use out of their air-operated tools and machines.

A fault that is guarded against is failure to maintain adequate air pressure in plant lines to operate tools at their recommended speeds. Most pneumatic tools are designed to use air at around 90 pounds pressure. When supplied with air at 60 pounds pressure they may do as much as 40 per cent less work than they should. But because the tools continue to operate at the reduced pressure, it is not obvious to the casual observer that their output is below that which would result if they were being supplied with air at the proper pressure.

A drop in air pressure may be due to various causes. Oftentimes it is attributable to failure to add to the compressor capacity to keep pace with an increase in the number of air-operated tools and machines. A constant-speed compressor can deliver only a given volume of air per minute at a prescribed pressure, and if this volume is less than the combined requirements of the tools and machines in service, the line pressure necessarily drops.

Even where the compressor capacity is adequate, pneumatic tools are in some cases handicapped because of undersized branch lines and hose connections. Under such circumstances the tools cannot obtain the proper amount of air because of line friction. Thus, even though the pressure in the main delivery system may be adequate, the pressure at the tools may be 10 or 15 pounds too low, and the work of the tools is reduced accordingly.

Then there is the matter of leaks. Although these may be small and of little consequence individually, the combined effect is loss of much valuable air and lower pressure in the system. As escaping air is not visible and, amid factory noises, not always audible, nobody pays much attention to it. A similar leak in a steam line would receive immediate attention because everyone would notice it.

Many plants have adopted the practice of testing the compressed-air system for leaks at regular intervals. This is generally done on a Saturday afternoon or a holiday, when little or no work is being done in the factory. To determine the amount of leakage, it is necessary only to run the compressor plant until the system is pumped up to the normal operating pressure, and then to run the compressors just enough to hold that pressure. In this manner it is an easy matter to calculate the volume of air that is normally wasted on account of leakage.

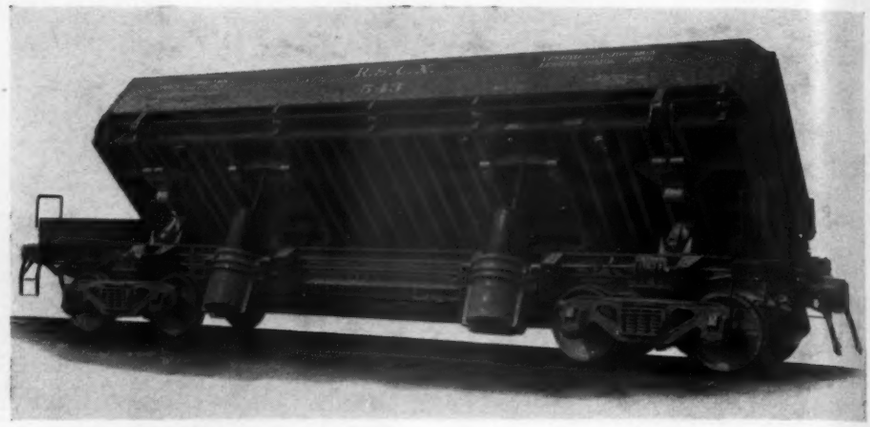
Another obstacle to effective air-tool operation is moisture in the air. The moisture content varies with the climate and the seasons; but in most parts of the world it is sufficient to warrant attention. When humid air passes through a compressor the moisture is condensed and squeezed out of it, just as it can be wrung from a sponge. Most of this moisture can be eliminated by passing the air through aftercoolers immediately after it leaves the compressors. Depending upon the length of the plant lines, uses of the air, and other factors, it may also be advisable to install traps and separators elsewhere in the delivery system. If moisture is present in too great a quantity, it passes through tools and machines, washes away the lubricant, and causes sluggish operation, with attendant excessive wear and rusting. In cold climates, water may also freeze in the lines and burst them.

Periodic attention to the aforementioned matters will have a twofold benefit: it will reduce the cost of compressed air and it will increase the amount of its productive work.

Two-Way Dump Car for Large-Scale Operations

AN EXTREMELY flexible type of dump car for handling large quantities of materials is being built by the Pressed Steel Car Company, Inc., for railroad, open-cut mining, and large-scale industrial operations. It is equipped for 2-way dumping, and permits cars to be unloaded individually or in groups of two or more. Dumping is effected by means of quick-acting air cylinders which are disposed vertically, two on each side. These move the body from normal upright to full dumping position, the volume of air required depending on the size of the car and local conditions. It averages 80 cubic feet at 100 pounds gauge pressure, and is stored in a receiver with which each car is provided and which draws its supply either from a stationary unit or, in the case of railroad operations, from the compressor on the locomotive.

The piping and valves on each car are so arranged that the flow of air from the receiver can be directed to the cylinders on one or the other side simply by setting the handle of a small valve. With half of the system cut off, the air is admitted to the desired cylinders by means of the dump valve located at a convenient point at the rear of each car. Loads are dumped in four to five seconds, after which the air in the cylinders is exhausted to the atmosphere and the body returns to its normal position



by gravity. In order to reduce dead weight, these dump cars are constructed wherever possible of alloy steels. They range in capacity from 12 to 50 cubic yards water level—that is, flush with the top, and are capable of carrying loads of from 20 to 75 tons. The one illustrated here can haul 50 tons of material.

Ammonia Clears Mine Air of Nitrous Fumes

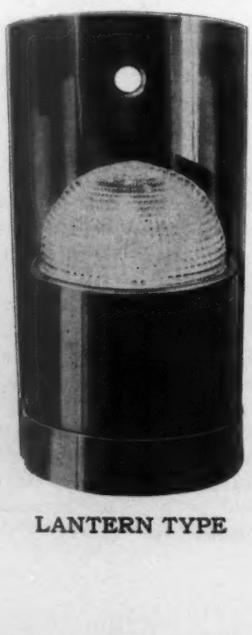
IN A paper presented at a meeting of the Mines Safety Committee held in Kalgoorlie, Australia, H. C. Dod, of the Kalgoorlie School of Mines, gave the results of experiments made by him with "gas bullets" to improve mine ventilation—more specifically, to remove nitrous fumes from working areas following firing. The bullets are described as small cylinders containing compressed chemicals—mainly magnesium oxide and ammonium salts—that liberate free ammonia when the charge in a hole is set off. One bullet is inserted between two sticks of explosive; and when the charge is detonated, the cylinder is blown to bits and the ammonium salts disintegrate into free ammonia and certain acid radicals. The latter subsequently combine with the magnesium oxide and are removed from the sphere of action, while the ammonia attacks any nitrous fumes—really nitrogen peroxide—that may be present. Nitrate and nitrite of ammonia are formed and fall to the ground, where the temperature is too low to cause them to dissociate. They do not decompose, and, even if mixed with the ore, do not cause any trouble in milling because the quantity is too small.

Many experiments have been made, says the *South African Mining and Engineering Journal*, and have shown by actual qualitative analyses that the bullets serve to free the mine air of nitrogen peroxide. Miners who have used them report that the resultant air is pure and refreshing in comparison with that after an ordinary blast. While one of the chemicals in the charge evolves oxygen when heated, the physiological effect referred to is probably attributable mainly to the absence of the nitrous fumes which are a definite factor in making the mine air smell "heavy." It should not be inferred from the foregoing that the air after firing is rendered harmless. There still remain the oxides of carbon, of which carbon monoxide is the deadly one. However, no miner would go back to a face after a blast without first having allowed the compressed-air lines to blow for a while in order to dilute the atmosphere to a point where the danger of a lethal concentration of carbon monoxide no longer exists.

Electric Lamps for Emergency Use

FOR emergencies, Triumph Explosives, Inc., has developed an electric lamp that is said to be absolutely dependable no matter how long the interval between installation and actual use. The feature of the new unit is the dry-cell battery, which differs in one vital particular from that in general service. In appearance, method of contact, and voltage capacity it is like the conventional type; but its cells are packed in such a way that they remain inactive until the lamp is needed and the bottom of the housing is struck against a solid object. That blow releases the energizing fluid. which is contained in a sealed glass vial around which the cells are grouped, as one of the accompanying illustrations shows. The lamp is available in several designs for marine, transportation, industrial, and hospital use, and in sizes that will burn continuously for from 5 to 20 hours. It has been approved by the Underwriters' and other laboratories.

A TRUCK FLARE



LANTERN TYPE

INACTIVE BATTERY

Industrial Notes

Aluminum ladders with hand rails and with nonslip rungs are available in lengths up to 36 feet and in varying widths.

Wonder is the name of an improved machine that is said to cut all kinds of core wire and rods up to and including 5/8 inch in diameter. It measures 15x8x4 inches, and the cutters are made of hardened die steel.

According to a report of the mining, metallurgical, and chemical branch of the Dominion Bureau of Statistics, Canada's mineral production reached an all-time high in 1939 with a value of $470,179,000. This represents an increase of 3 per cent over the previous record in 1937.

Norma-Hoffmann Bearings Corporation, Stamford, Conn., has announced that its diminutive precision ball bearings, ranging in bore from 1/4 to 1/8 inch and in outside diameter from 5/8 to 3/8 inch, can now be obtained with cages. Heretofore they have been available only in the retainerless type. A new data sheet covering these bearings can be obtained from the company

A MAGNET HOLDS HER

This 100-pound girl is being held up by a 3/4-ounce piece of sintered alnico magnet, a new development of the General Electric Research Laboratory. Alnico is an alloy of aluminum, nickel, and cobalt that was produced in 1936 by Goodwin H. Howe, a G-E research engineer. By sintering the material and assembling it in a mounting of brass or iron, it is possible to make the magnetic field pass through many air gaps, instead of the usual two, in bridging from pole to pole, and this is responsible for the greater power obtained. Tests have shown that such an assembly will lift and hold 4,450 times its own weight. The new assembly has not yet been placed on a commercial basis. By itself, an alnico magnet has a normal lifting power of 500 times its own weight.

To keep fingers and hands out of harm's way, the Industrial Products Company has provided a long-handled vacuum lifter primarily for the operators of low-stroke stamping machines and die presses. It can be used to pick up, feed, and position work accurately, and is said to hold securely

either flat or curved blanks of sheet metal, tinplate, fiber, etc. Films of moisture, oil, or grease, that normally interfere with handling, increase the holding power of the lifter, which is released instantly by slight pressure on a lever. The tool is made of duralumin for lightness and strength.

Chromatin is the name of a powder that, when mixed with water, forms a noncorrosive, stainless preparation that is designed primarily for retinning or resurfacing food containers such as vats in dairies, and the like. It is applied by a brush and then subjected to the flame of a blowtorch. The film is said to be three times as hard as tin and suitable for all metals except aluminum and lead.

Fountain-type stencil brushes with aluminum instead of brass barrels, caps, and heads are announced by the Diagraph-Bradley Stencil Machine Company. There are two types of this improved marking tool: one designed to provide a continuous supply of ink to the brush and the other a measured quantity controlled by means of a push button. The barrel holds enough ink to stencil about 1,500 addresses.

Where many long-distance telephone calls are put through, it might be helpful to use a Chronoscope, a new timing device offered by the Northwestern Clock Company. It measures 3 3/4x3 1/4 inches, is provided with a desk or bracket mounting, and is plugged into a 110-volt, 60-cycle socket. A switch on the face of the instrument sets it in operation: and a complete revolution of the synchronous-motor-driven dial indicates six minutes of elapsed time.

In the manufacture and maintenance of bearings and other surfaces that need to be trued, it is the general practice to use a Prussian Blue paste to locate the irregularities. Depending upon whether the bearing is round or flat, the compound is applied to a master shaft or straight edge which is rubbed against the bearing. If there are any high spots on it, the paste will leave telltale marks so that they can be scraped off by a skilled mechanic with a special hand tool. These operations are repeated until the surface is uniformly blue throughout, an indication that it is smooth. The difficulty with this work in the past has been the lack of a standard preparation. Such a compound has recently been put on the market by The Dykem Company, and Hi-Spot Blue No. 107, as it is designated, is said to be intensely blue, soft, and free from grit. What is more important, a thin coating will remain wet and transferable indefinitely, thus saving time and effort in removing dried paste from master and bearing surfaces and in rebluing them. The material is put up in collapsible tubes.

Ingersoll-Rand Company has announced two new types of light-weight riveting hammers for the manufacture of airplanes, automobiles, small boats, refrigerators, metal furniture, radios and electrical appliances, and other products calling for the use of aluminum, dural, or soft-iron rivets ranging

WITH OFFSET HANDLE

One of the AV riveting hammers of the slow-hitting type. Exclusive of the rivet set, this unit is 6 1/2 inches long and weighs 3 1/2 pounds. It drives 3/16-inch cold rivets.

in size from 1/8 to 1/4 inch. Each type can be had either with a pistol-grip or an offset handle or with a pushbutton throttle to meet varying requirements. The AV-1, AV-2, and AV-3 riveters are short-stroke tools for fabrication generally, while the AV-11, AV-12, and AV-13 are long-stroke, slow-hitting machines designed especially for building airplanes. They range in weight from 2 pounds to 5 pounds, 13 ounces. All are provided with an easily adjustable power regulator and a standard quick-change rivet retainer, and can be readily adapted for other work such as light chipping, scaling, and calking. Detailed information about these riveting hammers is contained in a folder entitled *Air Tools for Aircraft*, which can be obtained from the company's main office at 11 Broadway, New York, N. Y., or any of its branches.

Pellets that will serve as temperature indicators within the "black" range below 1,000°F. are for sale under the trade name of Tempils. They are made so that each melts long enough before a predetermined temperature is reached to give warning of

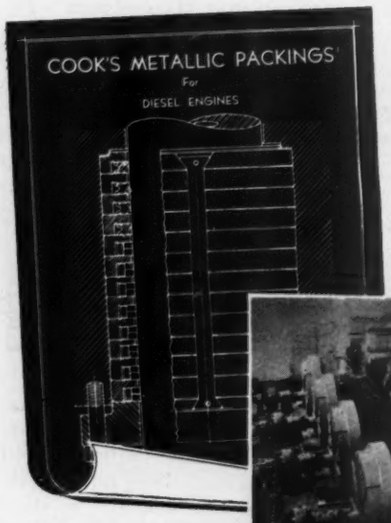
that fact. They come in 100° steps, starting at 200°, or in 50° stages, if requested, and are properly marked for identification. It is claimed that they can be used with safety in contact with regular work or surfaces undergoing testing, and that they will not cause corrosion or pitting, nor leave a stain that cannot be readily removed.

Concrete mixed with bits of soft-iron wire is described in a British patent recently granted a Yugoslav inventor. The flexible reinforcing is from 4 to 6 inches long and about 0.04 inch in diameter, and is said to have a tendency to conform to the contours of the aggregate. The composition, of course, varies with the structure, but a normal mix contains on an average 110 pounds of wire per cubic meter (1.3 cubic yard). When poured, the pieces on the top surface are drawn out evenly by means of a fork. there being enough of sufficient length to serve as keys to bind the succeeding layers firmly together. The concrete is said to have exceptional tensile and shearing strength.

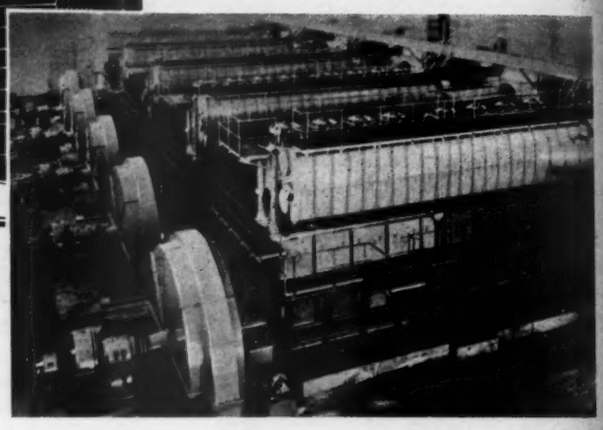
In addition to carrying self-righting rafts that will accommodate everyone on board, all French merchantmen, according to a recent Government decree, are to be safeguarded against torpedo and mine attack. The Russian engineer Yourkevitch, who designed the hull of the liner *Normandie*, proposes to do this by means of compressed air. While details of his scheme are lacking, it is reported that the holds are to be made airtight by the use of sheets of specially compounded rubber and are to be kept under pressure. In case of attack and a sudden explosion, the compartment or compartments affected would not be flooded provided, of course, the pressure of the air could be maintained at a point high enough to offset that of the water attempting to rush in. In other words, they would virtually become diving chambers such as are used in salvage and submarine work.

Research with copper, which has extended over a period of ten years and run into seven figures has brought its reward, according to the president of the Phelps Dodge Copper Products Corporation. The new material, known as PDCP, is said to have exceptional conductivity, ductility, and fatigue resistance, and, what is of particular interest, is free of surface imperfections that might penetrate insulation and cause short circuits in motors and transformers. It is made by a patented process that eliminates casting and rolling, and is formed into smooth and compact bars, rods, strips, and other commercial shapes by extrusion in the presence of a heated reducing agent which removes any oxygen remaining in the refined copper. Although the company is planning to grant licenses for the manufacture of PDCP, it is to be produced for the present in a unit erected for the purpose at its Bayway plant.

On the tough jobs...



it's COOK'S METALLIC PACKING...



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